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INDUSTRIAL GROWTH AND THE COMPETITIVE SYSTEM.*

BY

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Because it is intimately related to so many other industries, a brief examination of the development of the oil industry seems to afford a good starting point for a consideration of the subject chosen for this paper, "Industrial Growth and the Competitive System." Beyond that, I have had a certain familiarity with the oil business, and have noted that people are apt to talk most intelligently about subjects they know something about.

It is commonly but mistakenly said that petroleum was "discovered" by Drake when, in 1859, he drilled the first oil well. But in fact petroleum and some of its uses had been known for thousands of years. The ancient literature of the Near East, China and Japan contains references to its uses. There is respectable surmise that the substance wherewith Noah was commanded to "pitch the ark within and without" was asphalt—a residue from evaporated petroleum. Getting down to more modern testimonies, we know that in Scotland James Young produced kerosene and fuel oil from "an oil spring" a decade before the Drake well was bored, and later extracted petroleum from the shales which are still worked in

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Scotland. In this country there were small petroleum refineries long before the Drake well; and Pittsburgh, many years before Drake, considered lighting its streets with kerosene. George Washington's estate included a "burning spring" in what is now Wirt County, West Virginia. He estimated its value as near half his estate, and adjured his heirs not lightly to part with it.

But it was only with the rapid efflorescence of science and invention in our modern epoch, that industry as we know it began to develop. In this epoch progress has been so rapid, change so constant, that society has been continually confronted with new and complex problems. It has seemed possible that some illumination of these problems may be drawn from a consideration of their relations to the industry of petroleum.

The American Indians attributed medicinal value to petroleum, and many white pioneers accepted this aboriginal appraisal; so that medicinal uses long gave its chief value. Then came the use of kerosene as an illuminant; while the development of power machinery called for unprecedented quantities of lubricants. Whale oil, tallow and vegetable oils had been the favorite illuminants and lubricants, but there were not enough of these to supply the multiplying steam engines and the machines they propelled. Quantity production of petroleum came just in time to insure adequate lubricants for the machine age; and so petroleum started on the career in which new processes have constantly added to the number of commodities extracted from oil, until these now number far into the hundreds.

In early oil refining by simple distillation, the most valuable product was kerosene. But it was long impossible completely to separate all the gasoline from the kerosene; and so lamps required to be handled with great care. The gasoline was a nuisance, and a dangerous one. About its only usefulness was to remove grease spots. To run it off into sewers or creeks, with a chance of blowing up the sewers or setting the streams on fire, became a highly unpopular mode of disposal. Yet for many years this quick-tempered stuff for which today the whole world carries on a tireless quest, went to waste. Not until the invention of the internal combustion engine, in

which a small proportion of gasoline vapor mixed with air afforded the cheapest power, was the problem of gasoline solved. Then the gasoline engine was hitched to a high-wheeled buggy, and gasoline quickly became the most prized of petroleum products.

The petroleum industry was still in its swaddling clothes when the automobile appeared. The Drake well was followed by the "petroleum boom," one of the most remarkable periods of industrial frenzy on record. Yet at the end of ten years after 1859, the annual production of petroleum was only 4,215,000 barrels, which compares with 1,090,000,000 barrels in 1936.

The first four decades after Drake's discovery, growth was slow compared to its rate since the beginning of the present century. From 4,215,000 barrels in 1869, oil production rose to 63.6 millions in 1900. Then, with the automobile era, began the real modern expansion. By 1910 our production was 209 million; by 1920, 442 million; by 1925, 763 million; by 1930, 898 million; and in 1936 it went to 1090 million barrels.

We may speculate with some interest as to what might have been the attitude of a National Planning Board, if one had existed, in the year 1900, toward the automobile and oil industries of that day. There were then about 8,000 motor cars in the country, consuming about 3,360,000 gallons of gasoline a year. That would operate the motor vehicles of today about an hour and a half! One may imagine Henry Ford, with his vision of the automobile's future, appearing before the Planning Board, to ask that in its program for the next two or three decades it consider providing a few billions of capital, along with the material and labor, for his industry. The planning authorities would have recognized Mr. Ford as a mild lunatic. They would have asked where he hoped to get the gasoline to operate all these cars, pointing out that neither the gasoline nor petroleum from which to make it was anywhere in sight. So Mr. Ford's demands would have been rejected. A sophisticated public would have laughed at Ford when the Planners set down genius as insanity and inventive capacity as lunacy;—and that would have ended foolish talk about horseless carriages and flying machines.

Fortunately, there was no Planning Board to head off Mr. Ford's folly. Without bothering about where his gasoline would come from, he went ahead and presently was turning out 1,000,000 cars a year. And, there being no Planning Board to interfere, the petroleum industry kept right in step, always meeting the demands. Spurred on by the hope of profits, it set about boring more holes in the search for more petroleum, and sometimes finding it; it tried out new areas, brought in new producing fields; used geology and geophysics as aids in its search; developed deeper drilling; built pipe lines and tank ships to provide cheap transportation; erected more, and bigger, and increasingly complex refineries. And so, each year accomplishing things that a year earlier would have been impossible, the oil industry kept always ahead of the thirst of those multiplying millions of motor cars.

By 1925, 20,000,000 motor vehicles were calling for—and getting—nearly 10,000,000,000 gallons of gasoline. Public demand was pushing the automobile industry, and the automobile builders were urging on the petroleum industry; and all were marching on together. Unfettered enterprise, initiative, invention, competition, were accomplishing the things that our hypothetical Planning Board of 1900 had recognized as beyond the range of reason.

However, about 1925 the economic planners demanded an inning. They had been watching this development and now began to warn the country that its petroleum would soon be exhausted. This sort of gloomy prophecy had been popular, indeed, from the early years of the industry. In 1908 David P. Day, Chief of the Geological Survey, had estimated that our petroleum reserves were between 8,014,000,000 and 22,514,000,000 barrels. Since then the country has produced considerably more than twice the minimum figure, and is now rapidly nearing the maximum; yet, production in 1936 was the largest on record. From present indications the production in 1937 will greatly exceed that of 1936.

In 1918, another Chief Geologist, Dr. David White, revised the figures; if his conclusion had been correct as to the reserves at that time, the country would have been entirely without petroleum before the end of 1930.

Finally, in 1921 the Geological Survey in coöperation with the American Association of Petroleum Geologists, again looked into these reserves and concluded that there were still 9,150,000,000 barrels to be taken from the ground. Since that time there has been taken out rather more than 13,000,000,000 barrels, and yet today our proved reserve is still a good deal larger than was the total estimate of 1921! Thus it appears that the vision of groups who calculated our petroleum resources was not better than that of the Planning Board which found that Mr. Ford was well intentioned but a bit crazy. If taken seriously, their predictions would have paralyzed these industries in their infancy. Their great contribution toward national advancement would have been impossible. The collateral industries that have prospered because of their requirements would never have felt their demands. Of these the number is legion—steel, rubber, cotton fabrics, leather, lumber, glass, cement, road building, and all the rest. One hesitates to picture our industrial scene of today, if planning authorities had had power to impose their restrictions.

So far as concerns future supplies of petroleum, recent discoveries and improvements in methods of finding and recovering crude oil should set at rest any misgivings about future supplies. In the last two years over 2,000,000,000 barrels of petroleum have been taken from the ground; but on the other hand new pools discovered and proved up have substantially increased the net reserve in the ground. As is well known, no recovery process short of actual mining has ever recovered nearly all the oil from the sands. But in recent years recoveries have been greatly increased by repressuring with gas and air and by water-flooding. These have been commercially successful in a number of areas and will be increasingly employed whenever the price incentive warrants. Finally, it must be repeated that all estimates of reserves deal only with fields that have been opened and so far drilled up that accurate judgments of their potentials can be formed. No account is taken of possible future discoveries, either in territory that has not yet been drilled or in the lower horizons of fields now opened but whose lower depths the drill has not yet penetrated. There are producing wells over two

miles deep and drilling apparatus now perfected is able to take the drill down to much greater depths when occasion requires. These very deep wells of course are costly, but on the other hand the tendency toward unit development of pools points to a time when much fewer wells will be required to insure as great or greater recovery in a given field. All this, without taking into account the certainty that coal and the oil-bearing shales can be drawn upon for almost unlimited supplies whenever demand and price shall justify, seems to set at rest any misgivings about where our motor cars will get their fuel in the future.

Now let me suggest how competition, enterprise, initiative, invention, research, and improvement of processes and methods have all contributed to produce the results I have outlined. The Drake well of 1859 was 68.5 feet deep. As I have said, there are now producing wells over two miles deep. Moreover, it is now possible to determine the character of geological structures in advance of drilling and so to ascertain with reasonable certainty whether the drill may reach oil. This has greatly reduced the chance of extensive and expensive borings in unproductive territory.

Everything that has to do with the mechanics, the engineering, the chemistry, the geology, the whole technique of finding, recovering, transporting and refining oil, has been constantly improved under the urge of competitive conditions and the demand for increasing supplies. I know of no other industry in which plants and processes become obsolete so rapidly. A refinery five years old is well on its way out. It may have cost millions, but no matter how great the cost, it must be kept up-to-date, must extract the largest quantity and highest quality of the most valuable fractions of the petroleum, at the lowest cost. Otherwise it operates at a loss because of the competition of more modern rival operators.

This unending succession of inventions, improvements, discoveries, processes, was inevitable. The engineers and scientists, in shops and laboratories, were constantly finding new uses for petroleum derivatives, and better ways to extract them. The car builders were calling for ever greater quantities and better qualities of fuel and lubricants. Nothing was ever static. It was a continuing evolution. To enumerate

these shifts and changes, and tell how they compelled reorganization of plants and methods, would be to trespass unduly on your patience. Instead, I may illustrate them with a brief account of a single one: the process of "cracking."

Cracking is one of the improvements through which it has been possible to get more out of the petroleum while continually reducing prices. As I pointed out earlier, kerosene was long the most prized petroleum derivative. As late as 1904 over 48 per cent. of refinery production was kerosene, and only 10.33 was gasoline. Then while gas and electricity were elbowing kerosene out, the motor car was rapidly bringing gasoline in, and refining had to be accordingly adapted. By 1934, no less than 46.55 per cent. of refinery production was gasoline, and only 6.01 per cent. was kerosene.

Petroleum is a compound of many substances, and there are numerous kinds of petroleum, each requiring more or less specialized treatment. In the early days a satisfactory kerosene was extracted from the Pennsylvania crudes. But when the mid-continent fields were opened, their petroleum was quite different and new processes had to be devised. It was even necessary to perfect new lamps; and American lamps went along with American kerosene, carrying light to all the world.

Later, the demand for gasoline necessitated another evolution; and this brings us to cracking. In simple distillation, when petroleum is heated in a still the lighter elements vaporize and escape first. These are condensed into naphtha and gasoline. Then, with a higher temperature, the next heavier elements are vaporized and condensed, giving us kerosene; and after these the still heavier parts which become lubricants, paraffine, asphalt and various others.

Now, the lightest elements, which give us gasoline, are made up of the smallest molecules and therefore are most volatile. It was discovered that under greater heat and pressure these larger molecules could be "cracked," and then became just as volatile as distilled gasoline. Thus it was possible to increase gasoline recovery.

The earliest cracking was done with what was called the shell still. Invention soon retired this and it was succeeded by the pipe cracking still, making yet larger recoveries pos-

sible. Today it is possible by cracking to convert 45, 60 and even 75 per cent. of the petroleum into gasoline, and the gasoline recovery is nearly twice as large as would be possible without cracking. To put it another way, about 1,000,000,000 barrels of petroleum are refined annually to give us our gasoline. Without cracking, it would require nearly 2,000,000,000 barrels. Further, the cracked gasolines are less liable to knock; this permits higher compression pressures in engines, and this in turn increases the amount of work per unit of gasoline used and per pound of engine weight. Thus we get cheaper cars, more mileage and higher efficiency.

Yet more recent is the hydrogenation process, by which hydrogen is added to the petroleum molecule, effecting changes that make it possible to convert substantially the entire barrel of crude into gasoline and lubricants. All these developments have been brought about as a result of the pressure of competitive conditions, the demand for better products, the aim to get ever more out of the crude, and the urge always to make lower prices possible. On this point I wish to be quite explicit. These industries have prospered precisely because their policies have always looked to larger production, wider markets and lower prices. Take first the motor car. According to the statistics presented by the Automobile Manufacturers Association the average passenger car of 1909 had a wholesale value of $1252; whereas the average passenger car of 1935 had an average value of $527, a reduction of 58 per cent.

But these reductions in initial cost only start our story. Again quoting the authorities just mentioned, as late as 1919 only 10.3 per cent. of cars built were closed; by 1935, 99.5 per cent. were closed. The usefulness of the open car of course was restricted to good weather; today our closed cars are even more needed in bad weather than in good; they have about twice the expectation of life that the car of 25 years ago had, and do much larger mileage per year.

Then consider the tires. In 1914 a tire for a light car cost $20 to $22, guaranteed for 3,500 to 4,000 miles. Today the corresponding tire costs about $14.65 and is good for 30,000 miles or more. That is, the motorist of 1914 paid $1 for 200 tire-miles; today he pays $1 for 2,048 miles.

Next, the motor's fuel. In 1920 the average cost of gasoline was, ex-tax, 29.7 cents per gallon; in 1935 it was 14.11 cents. In short, the average cost of owning and operating a car today, mile for mile, is just about one-fourth what it was twenty years ago; and it is a far more safe, comfortable and reliable car.

Finally, consider the good roads; the motor car has paid for these through gasoline and other special taxes. Last year about one-seventh of all taxes—federal, state, municipal —were on the ownership and use of motor cars.

Let me repeat that these things were accomplished by the most competitive businesses in the country; the direct result of constant, unrelenting competition. The evidences of that competition are brought to you whenever you look at the advertising columns of newspapers or magazines, at billboards or electric signs; or when you listen to the intriguing message with which the radio announcer points his moral and adorns his tale. Mass production, constantly improving methods, have made for continuously lower prices and wider markets. Profits have come from increasing volume at lower unit prices; from passing on to the consumer the benefit of every advance.

There hasn't been an iota of philanthropy, an ounce of idealism, a scintilla of unselfishness; nothing but sound business principles, working for profits, in an atmosphere of free enterprise and unfettered competition.

One of the most important factors in continuing reduction of costs has been a unique transportation system. Concerned with bulky and heavy materials, this is the only industry that has its own complete transportation organization. At first, petroleum was hauled in casks and wagons. Then the first pipe line was laid; and from this has developed a system of 112,000 miles which gridirons a large part of the continent.

In addition, the industry operated in 1936, 388 oil tankers of 1,000 gross tons and upwards, besides nearly 400 smaller vessels in harbor and coastwise service. These vessels bring petroleum from the Gulf, Caribbean and California to the refining centers, and distribute its products along the American coast and to all parts of the world. This American fleet of ocean-going oil-carrying vessels of 1,000 gross tons and

upwards comprises a total gross tonnage of 2,489,725 and an estimated deadweight tonnage of over 4,000,000. It can safely be stated that the American oil tanker fleet comprises from 40 to near 50 per cent. of the total deadweight tonnage of the American merchant marine.

Besides this, the industry owns over 150,000 railroad tank cars; about one-sixth of all carload freight by rail is petroleum and its products. If all tonnage moved by pipelines and tankers had to be handled by rail, the railroads would be overwhelmed and the cost would be so great that the industry would presently be paralyzed. Finally, petroleum requires many thousands of tank trucks to handle and distribute its products. This transportation system represents investment of some $2,000,000,000, or about one-sixth of the total for the industry, and provides by far the cheapest transportation ever devised.

The benefits of all these improved methods and facilities have always been passed on to the consuming public in low prices. This is shown by the Government's index of commodity prices. Within the last few days I have received these figures for November, 1936. Taking 1926 prices as 100, it is shown that last November's index figure for farm products prices was 85.1; for foods, 83.9; for hides and leather products, 97; for textile products, 73.5; for fuel and lighting products, 76.8; for metal and metal products, 87.9; for building materials, 87.7; for chemical and drugs, 82.5; for house-furnishing goods, 82.3; for miscellaneous goods, 73.4;—and then for petroleum products, the figure drops to 58.1; by a long way the lowest in the entire list.

One important reason for its efficiency is that the industry has always paid high wages. According to the U. S. Bureau of Statistics, average hourly earnings of all employees in manufacturing industries in July, 1935, were 56.9 cents; whereas petroleum refinery employees got 81.3. I will not burden you with statistics having to do with wages paid in other departments of the petroleum industry because refining is typical of them all. This policy of liberal wages has brought about one of the lowest rates of labor turnover, which always spells efficiency. If all industry had maintained employment and wages as this one has done, un-

employment would long since have been ended; for in 1934, 1935 and 1936, refinery employment was larger than in any year prior to 1929. In 1927 it listed 71,234 people and in 1936, 76,594. Further, there has been a steady gain in production per worker. One worker in 1921 accounted for only 7,485 barrels of crude, whereas in 1936 one worker accounted for 14,244 barrels. Such advances were a chief factor in lowering prices of products from year to year, even while commodity prices in general were persistently advancing. This brought the products within the buying capacity of a constantly larger number of people, and year by year furnished more employment despite the increasing productiveness of workers. The petroleum industry employs over 1,000,000 workmen directly, and through its purchases of steel and other products which it consumes there is furnished employment for over 800,000 additional workers.

This has been the experience not only of the petroleum industry, but of all the others of the automotive group. No economic directing authority could possibly have foreseen, plotted, planned and organized such an achievement. No trust or combination, private or governmental, could have accomplished it; it could only have been conceivable in virtue of wide-open invitation to all the genius, inventive capacity, organizing ability and managerial skill of a great people. Nobody must be barred, nobody's invention rejected, nobody's idea left untried. Everybody must have his equal chance; and under our system of free enterprise and equal opportunity, everybody got just that chance. The result is the achievement that has fairly made over the face of industrial America.

I have used the automotive group to illumine my thesis that only through free competition, equal opportunity and the profit incentive could such results be brought about. Of course, other industries afford like testimony. I might have cited the stories of radio, or aviation, or the moving pictures, or mechanical refrigeration. Or I might have gone back to the development of mechanical power following the invention of the steam engine; to the mechanization of agriculture or of textile production; to the building of our railroads; to the telegraph and telephone; to the production of electric light

and power;—to endless other marvels of the amazing century that is just behind us. All these wonders were wrought under institutions which assured every man the full opportunity to make the most of his talents, his abilities, his energies.

The Scotch lad who wondered about the dancing lid on his mother's tea kettle—and gave the world the steam engine—could never have imagined the consequences of his invention. And if not he, where would have been found the economic planners capable of visioning them? Turn your memory's clock back to the hostility and sabotage with which conservatives received the devices of Arkwright, Hargreaves, and the other inventors of textile machinery. They were sure that such devices would mean only ruin; they were bent on rooting out, wrecking and forbidding all such unholy contraptions. Their attitude was precisely that of certain people today who would have us believe machinery is a menace and invention a curse.

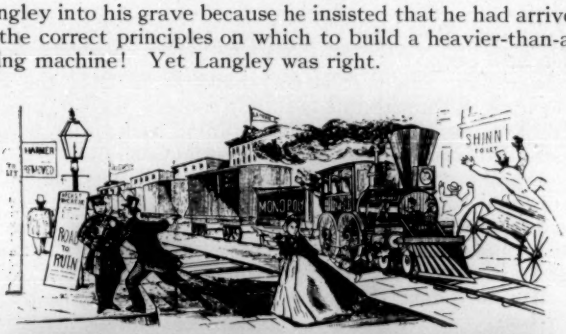
Why, within the lifetime of people not yet old, the first telephone was placed on the White House desk of President Grant. After a trial had convinced him that he could actually talk through it, he leaned back and said: "Yes, it is all very remarkable; but who on earth would ever want to use one of them?"

Now, President Grant was quite a man. He won a great war and was twice president. But I submit that that incident justifies doubts about the vision of any economic planning council he would have appointed. And as president, he might have had to appoint such a council.

Just one more instance. When it was proposed, almost exactly a century ago, to build a railroad into Philadelphia, there were protests so ardent as to verge on riot. Our economic planning authorities would have been in real danger of tar and feathers if they had weakly yielded to the siren song of Camden and Amboy! But they wouldn't have yielded. They would have known that railroads would scare the hens out of laying, the cows out of giving milk, and the stage coaches out of business, and in general would forward the most malevolent designs of the devil himself.

Let me remind you too, that it is only a quarter of a century since wise people were ridiculing Samuel Pierpont

Langley into his grave because he insisted that he had arrived at the correct principles on which to build a heavier-than-air flying machine! Yet Langley was right.



MOTHERS LOOK OUT FOR YOUR CHILDREN!

ARTISANS, MECHANICS, CITIZENS!

When you leave your family in health, must you be hurried home to mourn a

DREADFUL CASUALITY!

PHILADELPHIANS, your RIGHTS are being invaded! regardless of your interests, or the LIVES OF YOUR LITTLE ONES. THE CAMDEN AND AMBOY, with the assistance of other companies without a Charter, and in VIOLATION OF LAW, as decreed by your Courts, are laying a

LOCOMOTIVE RAIL ROAD!

Through your most Beautiful Streets, to the RUIN of your TRADE, annihilation of your RIGHTS, and regardless of your PROSPERITY and COMFORT. **Will you permit this?** or do you consent to be a

SUBURB OF NEW YORK!!

Rails are now being laid on BROAD STREET to CONNECT the TRENTON RAIL ROAD with the WILMINGTON and BALTIMORE ROAD, under the pretence of constructing a City Passenger Railway from the Navy Yard to Fairmount!!! This is done under the auspices of the CAMDEN AND AMBOY MONOPOLY!

RALLY PEOPLE in the Majesty of your Strength and forbid THIS

OUTRAGE!

Poster circulated extensively in Philadelphia and vicinity in 1839. (Reduced size.)

In conclusion, we may well keep in mind that only within the last three or four centuries has the human intellect been freed from the domination of the various breeds of economic planners. Only for so brief a time have men enjoyed freedom

to dream, to think, to imagine, to invent, to experiment, to match wits in friendly rivalry and fair competition. Yet in that brief period the race has progressed at a rate never before conceivable. Surely it is not thinkable that, in the light which shows through this twentieth century, a great, progressive people will be beguiled into turning back to the ways of controlled economics and dictated social programs.

What people need is more, not less of freedom for the individual to work out his own destiny. Government can help by safeguarding the common man's right to be himself—all of himself. It can protect against monopoly, tyranny, extortion, and every infringement of human rights. When it shall have done this much, it will have served its highest purpose.

I accepted to come here tonight because I have long been a member of the Franklin Institute and am greatly interested and firmly believe in its aims and purposes.

You who are here tonight are interested in science and research and your very livelihood is obtained by your technical skill.

All of us are deeply concerned today as to what will be the incentives and the opportunities for the development of science in the future. In this country our people are being taught that our prosperity, which so far exceeds that of any other country, is due entirely to our great natural resources. These speakers and writers do not explain why such countries as Russia, Mexico and several of the South American and South African countries, all rich in natural resources, fail to develop a prosperity comparable with ours, for they fail to recognize that the greatest of natural resources is scientific research and development; nor do they speculate as to what natural resources the other countries of the world might develop if they spent the same energy, initiative, invention, time and money in search and development that we do here in America. Such preachments are specious and endanger the very living standards of our people. All of us want to do our share of the world's work, but we have another and a greater ambition; we want to create something; build something which when it is handed down to posterity will make this world of ours a better and a finer place in which to live.

We want our children, because of what we have done, to be able to live richer and fuller lives. Sometime ago I stumbled upon a little poem, entitled "The Bridgebuilder," from which I have derived much comfort because it pictures what I have in mind far better than any words of mine could. I will close by repeating it.

An old man traveling a lone highway
Came at evening, cold and grey,
To a chasm deep and wide
Through which there flowed a sullen tide.
The old man crossed in the twilight dim
For that sullen tide held no fear for him.
He turned when he reached the other side
And built a bridge to span the tide.

"Old man!", cried a fellow pilgrim near,
"Why waste your time on your building here;
Your journey will end with the ending day
And you never again will pass this way;
You have crossed the chasm deep and wide;
Why build a bridge at eventide?"

The builder raised his old grey head;
"Good friend, on the path I have come," he said,
"There followeth after me today
A youth whose feet will pass this way.
This stream which has meant naught to me
To that fair-haired boy may a pitfall be;
He too must cross in the twilight dim—
Good friend, I am building that bridge for him!"

A Gas Fired Water Tube Boiler.—G. MURRAY BOYD in the *Gas World*, Vol. CVI, No. 2746, describes this new development in domestic gas boilers which is in contrast to the present well known fire tube boiler. He states that the water tube principle, though known to be more efficient, has been neglected owing to its "a priori" appearance of costliness and complication. The problem of applying water tube principles to small boilers has now been solved by the use of the thimble tube principle. This consists in arranging elongated thimbles, connected by their open ends to the water space, so that the thimble ends project into the flue or gas passage. By this means, an extraordinarily rapid heat transfer is obtained, due to the fact that the gases impinge at right angles to the water tube surface at high velocities and in a state of great turbulence owing to the staggered disposition of the tubes in a "nest." This arrangement incorporates all the conditions most conductive to rapid heat transfer by "forced convection" on the gas side and rapid circulation on the water side, since the water in the thimble is forced to enter and leave at a high speed by convection currents along the lower side and back by the upper side of the same tube. It is impossible for it to "stagnate" in the thimbles. The construction of this domestic gas fired boiler, known as the "Spiralflo" boiler, is such that the gas is burned completely in a combustion chamber where the products of combustion give up about 70 per cent. of their heat by direct radiation to the water jacketed steel walls. The products are then passed at higher velocity through the nest of thimble tubes where the greater part of the remaining heat is combed from the gases in a highly efficient manner. These gases are merely allowed to retain sufficient temperature to preclude condensation in the tube nest and flue. The new principles are now being successfully applied in domestic heating boilers, and in steam boilers up to 5000 lb. per hour evaporation.

R. H. O.

ULTRAVIOLET ENERGY IN DAYLIGHT— A TWO-YEAR RECORD.

BY

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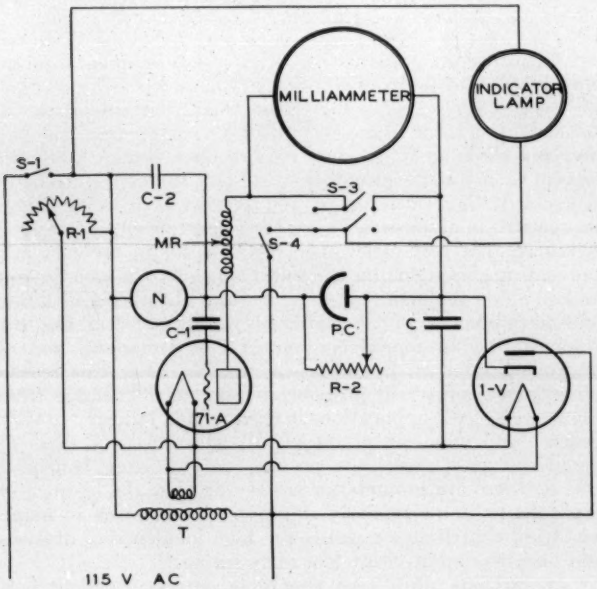
Natural light outdoors has been an environmental factor throughout the eons of evolution of life and health processes of living things. This fact alone makes it important to measure and to analyze the ultraviolet energy from the sun and sky throughout the day, seasons, and years. With the advent of the artificial indoor world and the development of sciences dealing with human welfare, and with living things in general, it assumes still greater importance.[1] Already it is known that ultraviolet energy is a factor in the cure and prevention of certain illnesses and it appears to be an adjuvant and an aid in the maintenance of health. In the construction and development of the artificial world mankind has the responsibility of reproducing natural environment, and of improving upon it, if and when possible. For this reason ultraviolet energy will probably be extended in usage from the many specific applications in therapy and industry to very general and wide-spread ones.[2] In addition to a mass of knowledge and experience proving or indicating beneficial effects, there are grounds for suspecting that the absence of exposure to it, particularly during winter months in many localities, contributes towards the high incidence of diseases and disorders in late winter or early spring.[3]

At any rate ultraviolet energy in outdoor daylight is a matter of scientific and practical interest. Very little work has been done with dependable apparatus and technique to determine its daily and seasonal variation over a long continuous period. Therefore, the authors set about this task several years ago and are herewith reporting measurements and analyses of this important component of daylight made continuously for a period of two years.

DESCRIPTION OF APPARATUS.

The ultraviolet energy was measured by means of a vacuum type cadmium-alloy photocell [4] developed for this purpose and a specially designed electronic integrator operated directly on the A.C. lighting circuit. Figure 1 shows the

FIG. 1.

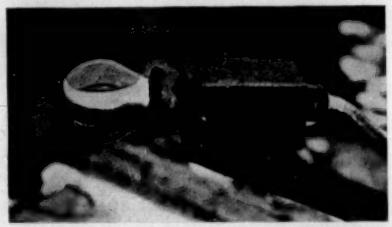


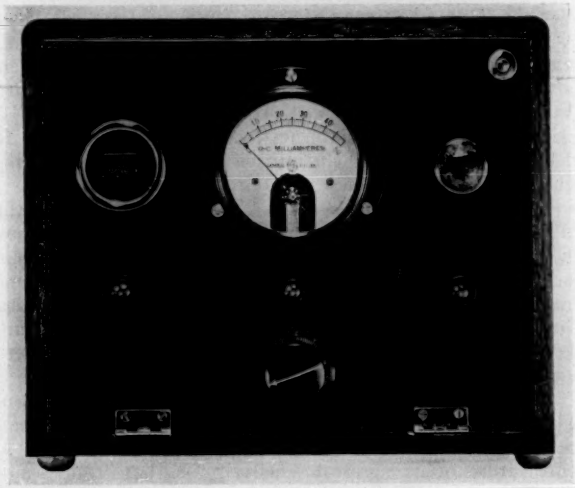
Wiring diagram of integrating ultraviolet meter (see text for description of operation).

wiring diagram of the meter and Fig. 2 illustrates the meter and the photocell. The meter was mounted in one of our offices and was connected by a waterproof cable to the photocell which was mounted on the roof where it was exposed to the entire sky.

Current from the photocell *PC* charges condenser *C-2* and when the voltage across it reaches a sufficiently high

FIG. 2.





Views of the ultraviolet meter and of the photocell.

value a flash discharge occurs through the small neon lamp *N*. This momentarily reduces the plate current of the 71A tube and when it returns to normal the counter *MR* records

this unit quantity. Hence the quantity of ultraviolet energy received by the photocell in any period of time is measured by reading the counter at the beginning and end of the period. This was done for each hour on the hour for two years. *R-2* is a very high resistance adjusted to compensate for a very minute leakage in the portion of the circuit containing *C-2* and *N*.

The meter responds at substantially the correct rate for ultraviolet energy varying over a wide range of intensity. Since the photocell is of the vacuum type, it is practically insensitive to voltage changes within the range encountered on the ordinary A.C. lighting circuit. Careful tests show that the sensitivity of the photocell is not appreciably affected by temperature changes throughout a range from 18° to 125° F.

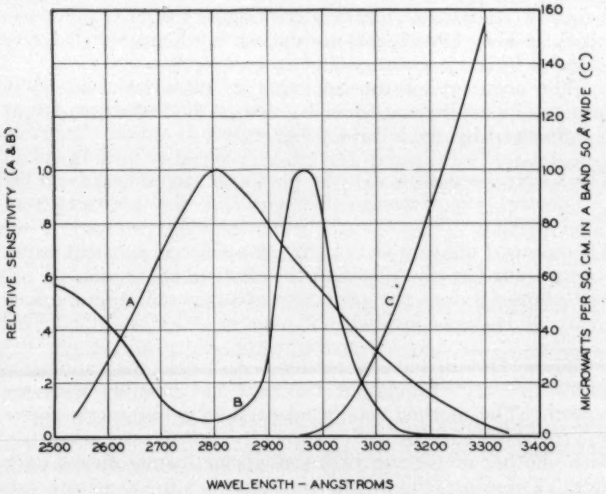
The photocell was mounted on the roof of a building at Nela Park, at an altitude of about 850 feet above sea level. Nela Park is located at the eastern edge of Cleveland, somewhat removed from the factory district, and the atmosphere is usually fairly free from most of the city smoke and dust. As shown by Fig. 2, the cell opening was horizontal. Its axis was in an approximate north and south direction. In this position it measured the ultraviolet from the sun and the whole sky, as received on a horizontal plane.

Curve *A*, Fig. 3, shows the spectral sensitivity of the cadmium-alloy photocell used in these tests. Curve *B* shows the relative effectiveness of equal amounts of ultraviolet radiation at various wavelengths in producing erythema (reddening) on average untanned skin of white subjects. Curve *C* shows the spectral distribution of energy in noon sunlight on September 10, 1936, for the spectral range λ 2975 to λ 3300.

It is seen from *A* in Fig. 3 that the sensitivity of the photocell covers the spectral range of ultraviolet radiation commonly of interest for its biological effectiveness. One excellent feature of its spectral sensitivity is that it does not respond appreciably to radiant energy of wave-lengths longer than λ 3300. Therefore, it does not overweight the long-wave ultraviolet as so many devices have in the past. This overweighting has tended to obscure certain interesting facts which our data reveal. In addition to this feature this photo-

cell was developed for the purpose of accurately appraising the erythemal effectiveness of ultraviolet energy. This is desirable not only for obvious reasons, but also because erythemal effectiveness is a practical guide to dosage and it provides a connecting link between various ultraviolet sources, dosages, conditions and effects. Extensive tests [5]

FIG. 3.



(*A*) Relative spectral sensitivity of cadmium-alloy photocell. (*B*) Relative effectiveness of energy of different wave-lengths in the production of erythema on average untanned human skin. (*C*) Spectral distribution of ultraviolet energy in noon sunlight at the earth's surface on September 10, 1936.

showed that our apparatus appraises erythemal effectiveness of energy differing greatly in spectral character as for example from a quartz mercury arc, (MAZDA) Sunlight Type S-1 lamp and (MAZDA CX) tungsten-filament lamp with special bulb. The photocell somewhat overrates the ultraviolet energy in outdoor sunlight and skylight as compared with the more powerful artificial sources of ultraviolet, but this was easily taken care of in the original calibration of the apparatus.

CALIBRATION OF INTEGRATING METER.

It was desired to evaluate the ultraviolet energy in terms of its power to produce erythema (reddening) on average untanned human skin. The spectral sensitivity of the erythemal response of this standard skin has been fairly well established as the result of several independent researches [6, 7, 8] and definite values have been adopted by the Illuminating Engineering Society.[9] Medical evidence indicates that energy in a narrow spectral region of wave-lengths longer than λ 2900, which is very effective in producing erythema, is also very effective in the prevention and cure of rickets.

The accuracy of the appraisal of ultraviolet energy in terms of its erythemal power by this method of measurement is influenced by the following factors:

The spectral sensitivity of the photocell used differs from the spectral effectiveness of energy in the production of erythema.

The spectral distribution of the ultraviolet in daylight is not constant but changes with the altitude of the sun.

The photocell does not perfectly integrate radiation received at all angles of incidence.

These factors have a tendency to cause the calibration factor to vary throughout the day and possibly with the season. The method finally adopted to calibrate the meter was to measure the ultraviolet from the sun and sky separately with another meter and photocell giving instantaneous readings. These measurements were made at frequent intervals throughout the day, and an integrated factor for the whole day was thus obtained, after correcting the photocell readings for angle of incidence of radiant energy. These measurements were made on 15 separate days distributed throughout the year. In order to obtain an absolute calibration of the second ultraviolet meter, giving instantaneous measurements, simultaneous measurements of direct sunlight were made with it and with a quartz monochromator, by means of which the spectral distribution of the energy throughout the range of interest was evaluated. These measurements were made several times on each of two days in September. Curve *C*,

Fig. 3, shows the spectral distribution of sunlight at noon on Sept. 10, the monochromator being pointed directly at the sun.

From the above measurements a calibration factor for the meter-photocell combination to convert its readings to E-vitons per sq. cm. was computed. One of the authors proposed the E-viton as a useful unit [10] which has been widely used and has been officially adopted to some extent. It is equivalent to 10 microwatts of ultraviolet energy after being weighted according to the erythemal response to equal amounts of energy of various wave-lengths, as shown in Fig. 3. For example, energy of wave-length λ 3022 has a relative erythemal effectiveness of 0.55; hence one E-viton = 10/0.55 = 18.2 microwatts at λ 3022. By means of this apparatus it was then possible to assign an absolute calibration factor to the integrating meter, to convert its readings to E-viton hours per sq. cm., based on comparative measurements made throughout the year. It is quite probable that this factor is not a constant, because of the variations in spectral and spatial distribution of the ultraviolet. However, our calibration measurements have been insufficient in number to determine a seasonal change in the factor, so an average of all determinations has been used. Our measurements indicate that this factor applies equally well to clear and to cloudy days.

RESULTS.

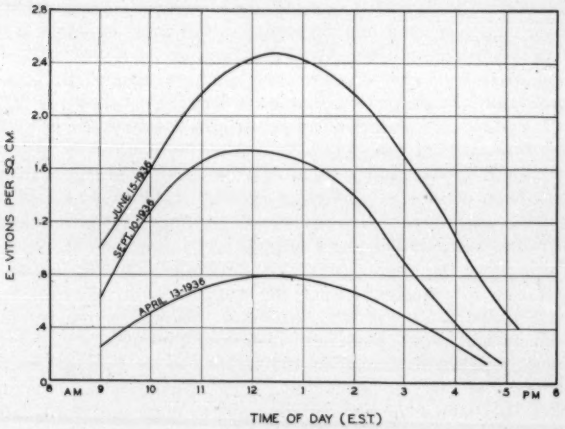
The variation of ultraviolet energy on a horizontal plane from the sun and entire sky throughout the day is shown for three very clear days in 1936 by the curves in Fig. 4.

Figure 5 shows how the ultraviolet on a horizontal plane from a clear sky varies with the portion of the sky considered. In the first graph the sky is divided into zones 10 degrees wide, each zone being marked to show the percentage of the total flux contributed by it. In the other graph the contribution by zones of equal area is shown. Table I shows the *relative* ultraviolet intensities of equal areas of the sky at different angular distances from the zenith, in a direction normal to each sky area considered.

Figure 6 shows the average ultraviolet energy incident on a horizontal plane during the noon hour on "clear" or sunny days throughout a period of two years. These values have

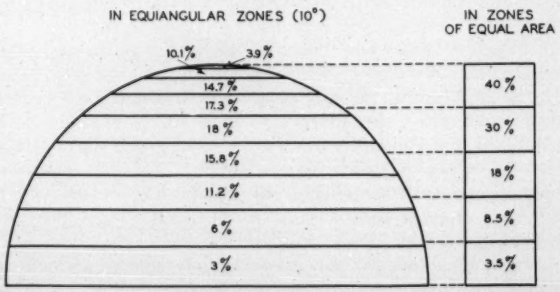
been plotted against the altitude of the sun, since this seems to be a principal cause of the seasonal variation of ultraviolet. Even for the same solar altitude there is a wide range of ultra-

FIG. 4.



Ultraviolet energy incident on a horizontal plane on three clear days in April, June, and September, respectively.

FIG. 5.



Ultraviolet energy from various zones of a clear sky incident on a horizontal plane at the earth's surface. Direct sunlight is excluded.

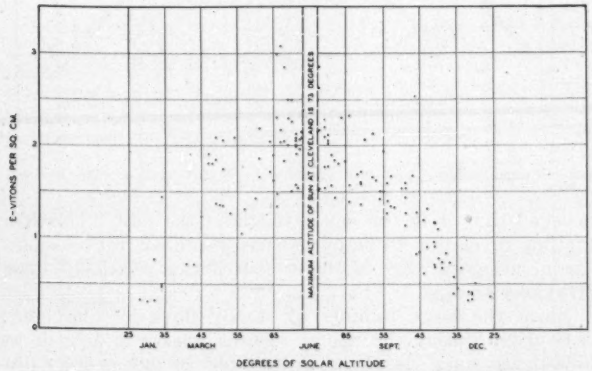
violet intensity. This is probably due in part to variations in clearness and constitution of the atmosphere, since our records only show whether the sun was shining at the begin-

TABLE I.

Relative Ultraviolet Intensities of Equal Areas of the Clear Sky at Different Distances from the Zenith (Average of Measurements Made in May, August and September).

Zone, degrees from zenith	Relative intensity
0 to 10°	100
10 to 20	87
20 to 30	85
30 to 40	81
40 to 50	79
50 to 60	74
60 to 70	64
70 to 80	52

FIG. 6.

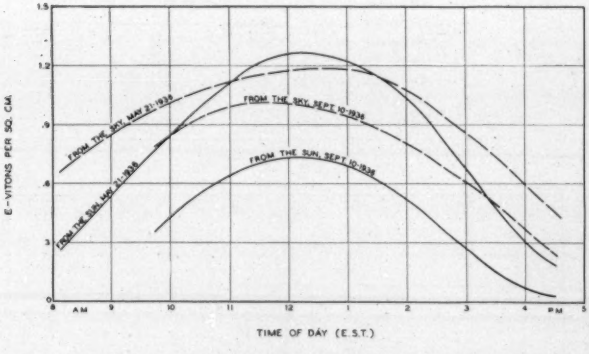

E-VITONS PER SQ. CM.
MAXIMUM ALTITUDE OF SUN AT CLEVELAND 18 TO 73 DEGREES
25 35 45 55 65 JUNE 65 55 45 35 25
JAN. MARCH SEPT. DEC.
DEGREES OF SOLAR ALTITUDE

Ultraviolet energy incident on a horizontal plane at noon on all "sunny" days for two consecutive years.

ning and end of each period (each hour on the hour) when the meter reading was recorded. However, other measurements have shown considerable variations when the sky appeared perfectly clear on different days near the same season.

For about eight months of the year a clear sky contributes more than half of the erythemal ultraviolet energy incident on a *horizontal plane*. Figure 7 shows the separate contributions of sun and sky to the ultraviolet on a horizontal plane on two typical clear days, May 21 and September 10, 1936. These show that for only two and a half hours on May 21 did the ultraviolet energy in direct sunlight exceed that from the entire sky, and on September 10 the component from the sky

FIG. 7.

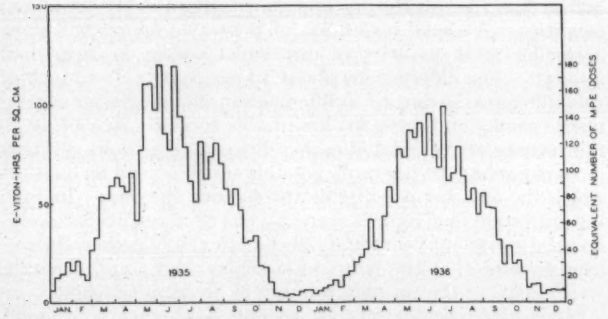


Ultraviolet energy incident on a horizontal plane from the sun and from the sky on two clear days.

exceeded that from the sun throughout the day. This is a startling revelation to many persons who have, for no sound reason, assumed that skylight contributes relatively little ultraviolet energy.

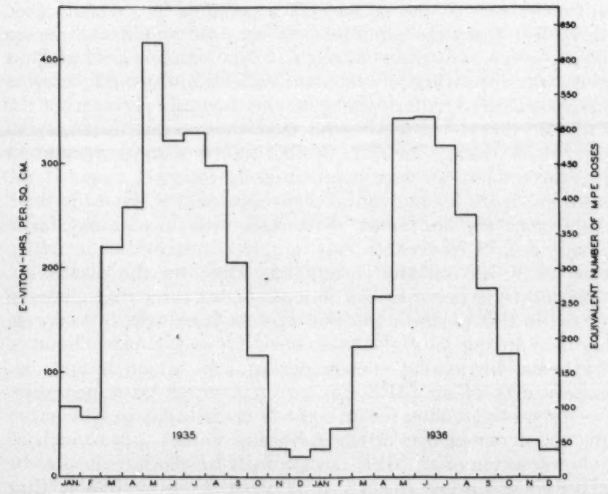
Since the large number of cloudy days in Cleveland, particularly during the winter months, makes it difficult to show the seasonal variation of ultraviolet by means of a daily plot, we have attempted to show this by means of weekly and monthly totals throughout the year in Figs. 8 and 9. These illustrate the seasonal variation more definitely, although even this method of plotting still results in somewhat erratic plots. Many of the estimates or curves in scientific literature showing effects of solar altitude on ultraviolet intensities are

FIG. 8.



Total quantity of erythemal ultraviolet radiation incident on a horizontal plane each week for 104 consecutive weeks or two years.

FIG. 9.



Total quantity of erythemal ultraviolet energy incident on a horizontal plane each month for two consecutive years.

based on clear days only. However, these are the exception rather than the rule for this and many other thickly populated localities. A casual inspection of these two figures will show a smaller total quantity of ultraviolet energy in 1936 than in 1935. The difference is about 19 per cent. How much of this difference is due to a difference in cloudiness, or atmospheric smoke and dust, we are unable to say. According to the records of the local Weather Bureau there were 38 days in 1935 having 100 per cent. possible sunshine and 63 days on which the sun was not visible throughout the day. In 1936 the corresponding records were 25 and 65 days, respectively. For the complete years 1935 and 1936 the Weather Bureau records show that the hours of sunshine were approximately 50 per cent. of the possible number of hours of sunshine.

It is of particular interest to find how much ultraviolet energy may be received through an open window. On a clear day in November measurements were made at windows facing southwest, northwest and northeast, on a vertical plane approximately at the position of a person's face when seated three feet from the window. In no case would the person have received any direct sunlight. The window area without glass was approximately five square feet, and would expose a person's face to radiant energy from about six per cent. of the total sky area. It was found that the average intensity of ultraviolet energy incident at the points of measurement at the three windows was approximately four per cent. of the total incident on a horizontal plane outdoors at the same time. Approximately the same percentage was also found for a cloudy day in November, but the actual ultraviolet intensity was much less on the cloudy day than on the clear day. Computations based on our measurements show that a person seated in this position on clear days in June would receive on his face during an eight-hour work-day 0.5 E-viton hour of erythemal ultraviolet energy per sq. cm. which is approximately 0.75 of an MPE dosage on average untanned skin. Corresponding values for an eight-hour clear day in November are about one-eighth of the foregoing values. Inasmuch as only a fraction of an MPE dosage daily has been proved to be effective in curing rickets, it is possible, even likely, that sufficient ultraviolet energy is available from the sky to be beneficial to persons seated for hours daily near open windows.

The ultraviolet exposure required to produce an MPE on untanned skin differs for different individuals, and for the same individual at different times. One of the authors found by tests on 11 white men that the quantity of ultraviolet energy required to produce an MPE was about 75 per cent. greater in January than in June.[11] On a clear day in July five white men were exposed to sunlight and skylight to determine the exposure required to produce an MPE on the inner forearm of each. The average time was approximately 20 minutes, the average quantity of ultraviolet energy being ⅔ of an E-viton hour. A scale of "equivalent MPE doses" has been placed at the right-hand edge of Figs. 8 and 9, based on the above test. This value has also been used throughout this paper in computing MPE dosage.

COMPARISONS WITH ARTIFICIAL SOURCES.

It is of interest to compare the radiation from a number of artificial sources of ultraviolet energy with that in daylight. The MAZDA CX lamp is a tungsten filament lamp, operating at a higher filament temperature than regular lamps of comparable wattage. It has a bulb which has a high transmission for ultraviolet in the region of erythemal and antirachitic value. It is a relatively mild source, but extensive tests [12] with patients suffering from rickets have proved that the energy from it will cure rickets when the exposures are for long periods even though the area of skin exposed is restricted to that of the hands and face. This is about 25 per cent. of the total area of skin of a child exposed when lying naked under an ultraviolet source. The Type S-1 and S-2 MAZDA Sunlight lamps employ arcs between tungsten electrodes in an atmosphere of mercury vapor. The Type S-1 is the more powerful of the two sources, as seen in Table II in which the exposure time for an MPE dosage is given for several sources.

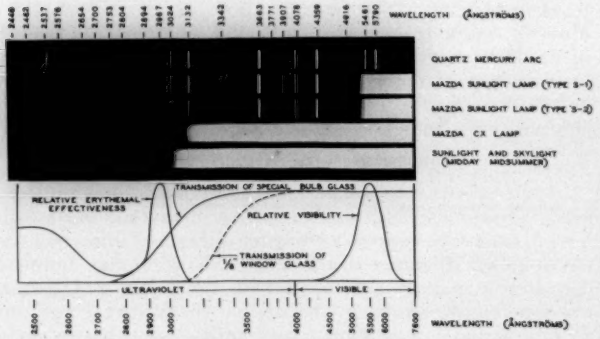
TABLE II.

Approximate Periods of Exposure Necessary to Produce a Minimum Perceptible Erythema on Average Untanned Skin, or an MPE Dosage, for Various Sources of Ultraviolet Energy.

Best noon sunlight in midsummer	20 minutes
MAZDA S-1 sunlamp at 30 inches	5– 7 minutes
MAZDA S-2 sunlamp at 30 inches	35–45 minutes
250-watt MAZDA CX lamps in polished aluminum reflector at 30 inches (300 footcandles on skin)	Approx. 7 hrs.

The CX lamps emit energy having a continuous spectrum in the ultraviolet region. The amount of energy decreases toward the shorter wave-lengths in a manner similar to the energy from sunlight. The Type S-1 and S-2 lamps combine a continuous spectrum from the electrodes with a line spectrum from the mercury arc. Figure 10 shows spectrograms

FIG. 10.



Spectrograms of various light-sources.

of these various sources. Since most materials are poor reflectors of ultraviolet energy, it is customary to use oxidized aluminum reflectors with "artificial sunlight" lamps.

MINIMUM DOSAGE.

The authors have actively coöperated in various researches, particularly with Dr. H. J. Gerstenberger (Babies' and Children's Hospital, Cleveland), to determine threshold dosages of ultraviolet for the cure of rickets. Test results published [12] and others publicly reported, but as yet unpublished, show that even such mild sources as MAZDA CX lamps are effective in this field when the exposures are for long periods. Many cures of rickets have been made with these lamps when exposures of 6 to 12 hours daily were made at illumination intensities of 35 to 100 footcandles. The quantity of ultraviolet energy received in that time was equivalent

to daily exposures of only a few minutes of sunlight in midsummer. Rickets has been prevented in the cases of premature infants with dosages equivalent to about one or two minutes of midsummer sunlight daily. In some of the other tests the children were fully clothed, only hands and head being exposed. The premature infants had their heads outside the hoods covering the cribs. Their bodies were naked with the exception of diapers, and heat and ultraviolet energy were supplied by two 30-watt lamps, in ultraviolet transmitting glass, placed at the top inside the hoods. The dosages were of the magnitude of 0.1 MPE daily on average untanned skin.

Some other tests, also unpublished, show that the antirachitic vitamin D may be added to the milk from wet nurses by irradiating them with MAZDA CX lamps. Other tests with adults and school children have shown that irradiation with artificial sunlight lamps introduces an antirachitic factor into their blood. Whether or not this factor is of positive value to healthy adults has not been directly proved.

Therapeutic benefits from ultraviolet are dependent in some measure on the intensity of ultraviolet energy per unit area, exposure time and skin area exposed. However, the benefits are not necessarily proportional to the product of these three factors. Much remains to be established pertaining to minimum dosage necessary for the variety of conditions possible such as area of skin exposed, duration and frequency of exposure.

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4. "Cadmium Magnesium Alloy Photo-Tubes," L. R. Koller and A. H. Taylor, *Journal of the Optical Society of America*, **25**, June 1935, 184.
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6. "Strahlentherapie," Hausser and Vahle, **13**, 1921, 41; **28**, 1928, 25.
7. "Reaction of Untanned Human Skin to Ultraviolet Radiation," M. Luckiesh, L. L. Holladay and A. H. Taylor, *J.O.S.A.*, **20**, August 1930, 423.
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10. "Nomenclature and Standards for Biologically-Effective Radiation," M. Luckiesh and L. L. Holladay, *J.O.S.A.*, **21**, July 1931, 420.
11. "Erythema," A. H. Taylor, *Medical Record*, September 18, 1935.
12. "The Cure of Infantile Rickets with Tungsten-Filament Radiation," Henry J. Gerstenberger and Arthur J. Horesh, *Journal of the American Medical Association*, **97**, September 12, 1931, 766.
(Also later results by Dr. Gerstenberger, as yet unpublished.)

V.
19

PHOTOELASTIC ANALYSIS OF T-TAIL STRESSES.

BY

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Assistant Professor of Machine Design, Mechanical Engineering Department, Institute of Technology, University of Minnesota, Minneapolis.

SYNOPSIS.

This paper presents the results of an investigation to determine the stress values and distribution in the T-tail connection for pole-pieces used in the construction of high-speed alternating current generators and motors. A comparison is made between the results of the photoelastic studies and the conventional methods of calculation.

INTRODUCTION.

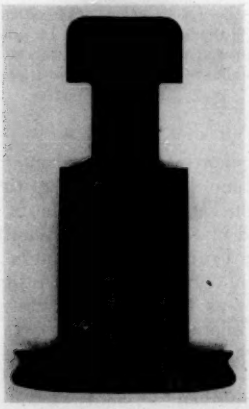
The recent application of the propellor type adjustable blade in water turbine design has set up the requirement that the waterwheel generator be capable of operating at 200 per cent. overspeed instead of the conventional 100 per cent. as necessary with Francis type runners. In order to use standard methods of construction, with the overspeed stresses nine times as great as the normal stresses, it was necessary to readjust the dimensions of the parts subjected to the increased centrifugal forces and to use materials having higher physical properties. The extent to which the more expensive materials were employed depended upon the accuracy and reliability of stress calculations. The photoelastic investigation described herewith was initiated to obtain an accurate picture of stress intensities and distribution in the most important rotor element, the link connection between the rotor proper and the salient poles.

One standard form of link connection is the T-tail, Fig. 1. Formed as part of the base of the pole punchings and end plates, a narrow rectangular neck subtends a wide rectangular section in the form of a T. The rotor spider, either cast or built of thin plates, is slotted to receive the pole T-tail. Keys in the form of wedges are driven in at each end of the spider to lock the pole in place.

The centrifugal force of the pole and its energizing coil is

transmitted through the pole T-tail to the T-slot in the spider. This force may be nearly 700,000 pounds for a pole two feet long traveling with a peripheral velocity at overspeed of 4¼ miles per minute. The width of the T-tail must be less than the body of the pole to allow assembly of the coil after forming. Its depth is determined by the proximity of slots for adjacent poles on the rotor, limited by the amount of material remaining between slots. A larger T-tail section is more expensive

FIG. 1.



Photograph of pole punching.

to punch and shape. Thus a careful analysis of the design characteristics of the pole T-tail is essential.

This problem was investigated on a similar type of connection between pole and spider by Prof. E. G. Coker [1] who reported the stresses in dove-tail joints primarily, although he also considered a second dove-tail joint in modified form shown in Fig. 13, page 315 of the reference, as a diagram of a tee-headed dove-tail joint with the stress distribution for the neck section tabulated in Table VI and shown on a graph

[1] "Photo-Elasticity," by E. G. Coker, JOURNAL OF THE FRANKLIN INSTITUTE, 199, No. 3, March 1925, pp. 289–331.

Fig. 16, page 320. The figure and graph are redrawn in this paper as Fig. 2. The sections in bending and shear were not discussed.

FIG. 2.

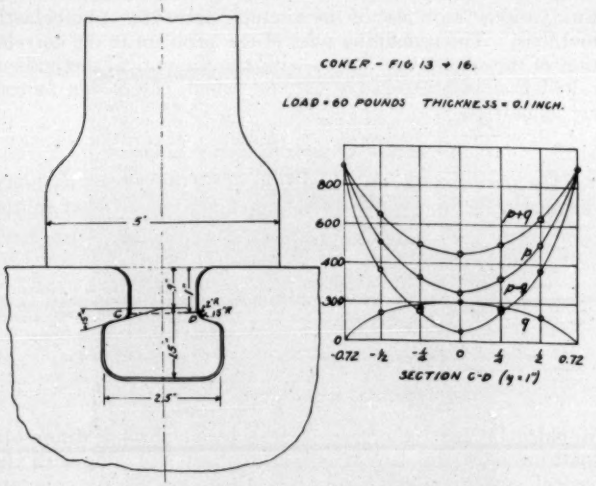


Diagram of a Tee-headed dove-tail joint—Coker.

In the book "Photo-Elasticity" [2, 3] by Coker and Filon, reference is made in the paragraph on Nuts and Bolts to the stresses in the head of a bolt. The lines of principal stress are shown for the bolt body and head, and the stress distribution at the cross-section through the centers of the radius of the fillets is presented and discussed.

In 1930, Baud [4] made note of an investigation of the stresses at the root of a turbine blade having a rectangular

[2] "Photo-Elasticity," by E. G. Coker and L. N. G. Filon, a text published by Cambridge University Press, 1931, pp. 683–5.

[3] See also reference 2 above, pp. 611–15.

[4] "Photoelasticity—and its Applications to Design," by R. V. Baud, *Machine Design*, 2, No. 11, 1930, pp. 29–31.

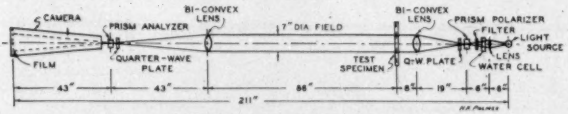
T-tail fastening, and figures of isochromatic, isoclinic and principal stress direction lines were shown. No analysis is given, however, for the numerical values of stress.

The main part of the present analysis consists in the determination of the principal and shearing stresses that exist at the various sections of maximum stress by photoelastic methods. The remaining part of the problem is the correlation of the photoelastic data with the theoretical methods of calculation in present day use, for which the design factors are submitted.

I. DESCRIPTION OF PHOTOELASTIC POLARISCOPE.

The photoelastic polariscope used in these tests is shown schematically in Fig. 3. This machine, constructed in the

FIG. 3.



Schematic diagram of photoelastic polariscope.

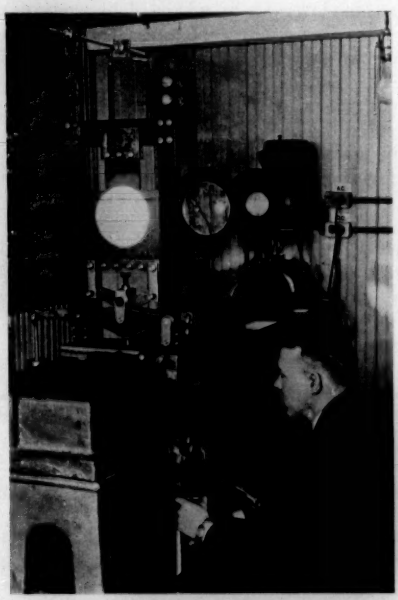
Machine Design Laboratory at the University of Minnesota Institute of Technology, is about eighteen feet long with the optical system mounted on lathe beds placed on concrete piers. The light source of the optical system is a mercury-vapor lamp with a Wratten 77A filter, as suggested by Prof. Frocht.[5] Fifteen millimeter Glan-Thompson prisms are used for the polarizer and analyzer with the quarter wave plates designed for the wave-length of the mercury-vapor light. The bi-convex field condensing lens have focal lengths of 19 and 43 inches with a 7 inch diameter field. The optical system is adjustable to obtain full scale photographs on a permanent 8 × 10 inch camera.

The stressing frame is built of structural bars and plates on a welded base. Above the base is nested a lever system which forms the weighing mechanism. The load is applied by means of a spring scale or a dead weight on an extending

[5] "Kinematography in Photoelasticity," by M. M. Frocht, Trans. A. S. M. E., *Applied Mechanics*, June 15, 1932, **54**, No. 11, pp. 83–96.

lever, and produces a magnification of 20 times on the model placed between the uprights in the light field. Needle bearings are used throughout, and the lever system is balanced to counteract the dead weight of the loading mechanism. Fig. 4 is a photograph of the specimen in the stressing frame.

FIG. 4.



T-tail model in loading frame of polariscope.

II. CONSTRUCTION OF MODEL AND DESCRIPTION OF TESTS.

Preliminary calculations of stress in the T-tail of the actual machine indicated that increased dimensions over the standard size would be required, and appropriate dimensions were established. The photoelastic model of the pole punching T-tail and the rotor slot was made from three pieces of Marbl-

ette material,[6] and machined by the same die makers who formed the dies for punching the pole laminations to reproduce commercial degrees of accuracy. The material was not annealed. Specimen bars were cut from the three pieces of Marblette after machining for test as beams in pure bending to obtain the photoelastic constants of the material. The model and the calibration specimens were ruled off at multiples of 1/16 inch intervals by means of an accurate scratching device on a surface plate. The pertinent sections on the model were marked by scratches 3/16 inches from the outer tangent of the fillet at the point of highest stress where the key made contact on the pressure surfaces. These markings are indicated on the sketch of the model in Fig. 5. With the model in the stressing frame it was necessary to tie the sides of the slot together with rods to obtain the equivalent built-in conditions of the solid plate spider between poles.

The means employed to determine the sum of the principal stresses, proportional to the change in thickness of the specimen under stress, was suggested by Peterson and Wahl [7] in their recent paper. Dr. Wahl kindly sent drawings of the device he developed, and an identical instrument was constructed except for the requirement of additional depth in the throat.

The measurements, both for the change in thickness and for the isochromatic photographs, were made within from three to five seconds after the load was applied.[8] In this manner the effect of creep was minimized, and maintained comparatively constant. The photographs taken were very close to full scale, the Brinnell microscope reading 16 tenth-millimeters for the distance between scratches of 1/16 inch. No optical distortion was observed within the range of the area requiring measurement. The values of the isochromatic fringes of stress were measured from photographs taken

[6] "A New Photoelastic Material," by A. G. Solakian, *Mechanical Engineering*, **57**, No. 12, Dec. 1935, pp. 767–71.

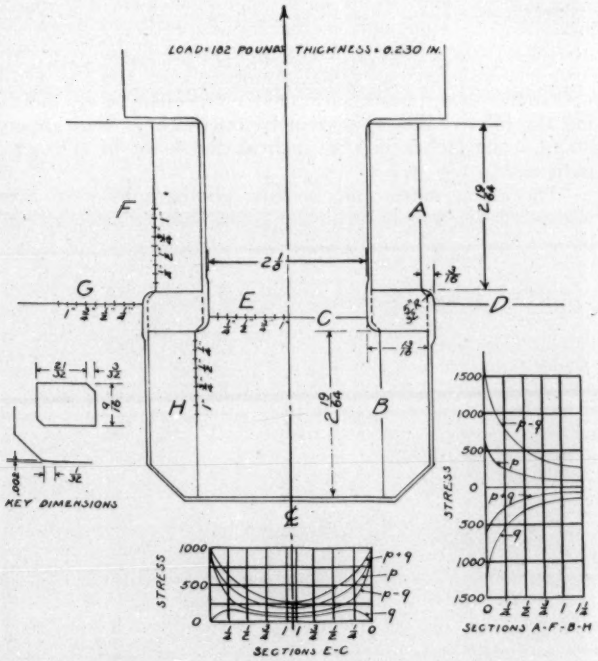
[7] "Fatigue of Shafts at Fitted Members, With a Related Photoelastic Analysis," by R. E. Peterson and A. M. Wahl, *Journal of Applied Mechanics*, Trans. A. S. M. E., **2**, No. 1, March 1935, pp. A-6, A-10.

[8] "Studies in Photoelastic Stress Determination," by E. E. Weibel, Trans. A. S. M. E., APM-56-13, **56**, No. 8, August 1934, p. 639.

before and after the multi-loading requirements of the lateral extension tests.

The photoelastic model was constructed three-quarter size with the fillets in the active corners cut at a radius of

FIG. 5.



Symmetrical T-tail and spider slot model with stress distributions.

3/32 inch, equivalent to 1/8 inch radius on the pole punching. The corners of the keys were bevelled at 45° as in practice. Photographs of stress and direction of stress (isochromatics and isoclinics) in the model under a tensile load of 182

pounds indicated extreme stress concentration at the junction of the corner of the key and the fillet. This stress, even at an appreciable distance from the fillet surface, was in excess of the allowable limit of the proposed material to be used in the machine. It was decided to increase the fillet on the punching and to eliminate the excessive concentration on the sharp corner of the key [9] by filing a taper at the end of the bevel. Reducing the sharpness of the corner of the key was suggested by Peterson and Wahl [10] but for a different purpose. The specific effect of these factors would require further attention. The photoelastic model was changed by increasing the fillet radius to 5/32 inch and the keys were tapered about 0.002 inches in 1/32 inch at the point of contact as indicated in Fig. 5.

The isochromatic and isoclinic photographs were taken with the revised model, and the experimental work continued by measuring the change in thickness under load at the various points marked for photoelastic study. In this manner the difference and sum of the principal stresses were determined and the individual values of the principal stresses, their direction, and the maximum values of the shearing stresses obtained. The specimen bars were loaded in pure bending and stress photographs and thickness measurements established the stress constants of the material. For all tests, the nearest measurement to the edge of the fillet was 1/16 inch, and the values of the edge stresses were extrapolated.[11]

III. RESULTS OF TEST DATA.

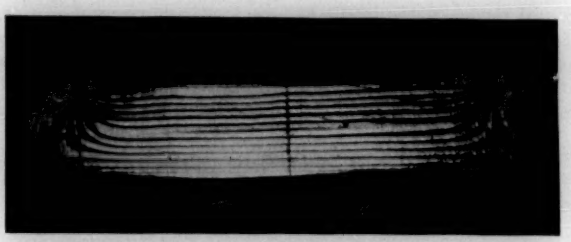
The calibration of the specimen bars in pure bending for the Marblette material 0.230 inches thick was 245 pounds per square inch for lateral extensions of 0.1 division on the Huggenberger Tensometer having a magnification of 1206; and 204.5 pounds per square inch per band or fringe for the isochromatic photographs. A representative picture of bending stresses in the calibration bar is shown in Fig. 6.

[9] See paper by M. M. Frocht, loc. cit., p. 3.

[10] See paper by R. E. Peterson and A. M. Wahl, loc. cit., p. 5.

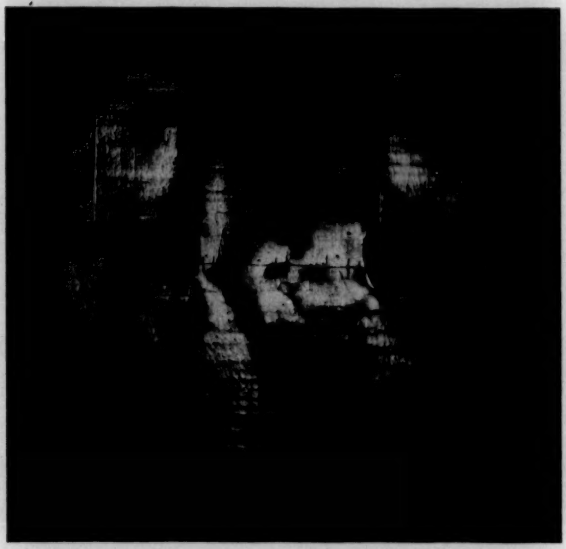
[11] "Stress Concentration Produced by Holes and Notches," by A. M. Wahl and R. Beeuwkes, Jr., Trans. A. S. M. E., APM-56-11, **56**, No. 8, August 1934, pp. 619–22.

Fig. 6.



Isochromatics of specimen bar in pure bending.

Fig. 7.



Isochromatics of T-tail and spider slot—Zero load.

The values obtained for the change in thickness of the T-tail model in the loading frame for the horizontal sections *D G E C* indicated differences within the accuracy of the measurements,—*i.e.* a single value would have applied to any of the four sections at identical points. Thus it was considered that the average of the sum of the principal stresses for

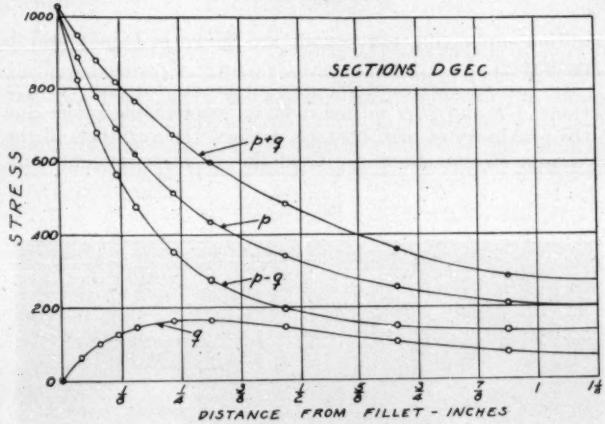
FIG. 8.

Isochromatics of T-tail and spider slot—182 pounds load.

the four sections would be more accurate than the individual values.

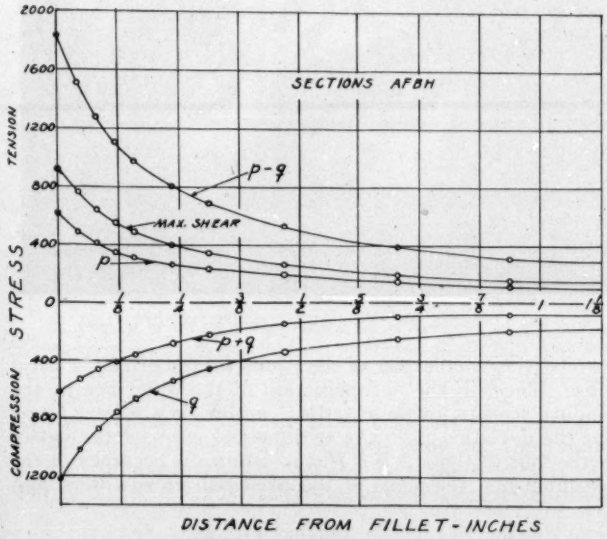
Similarly, from an analysis of the isochromatic stresses in these horizontal sections, the experimental evidence pointed to an average set of values. The isochromatic pictures of the T-tail model under zero load, and in the loaded

FIG. 9.



Principal stress values for sections *D G E C*.

FIG. 10.



Principal stress values for sections *A F B H*.

condition supporting 182 pounds are shown in Figs. 7 and 8, respectively.

The lateral extensometer measurements for the vertical sections *A F* and *B H* varied over an appreciable range due to the proximity of high contact stresses, the variation of the maximum stresses from the fixed line of measurement, and

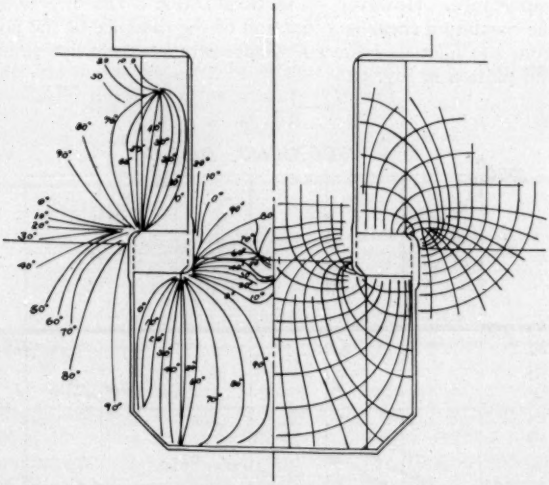
FIG. 11.

Zero isoclinics for T-tail and spider slot—182 pounds load.

the relatively smaller size of the values for the principal stress sums. Since, in the determination of the difference in the principal stresses for these vertical sections it was later found that the deviation from the arithmetical mean of the values for the four sections *A F B H* was within the accuracy of the measurements, the sums of the principal stresses were also

averaged together. As a result, it was considered that for the symmetrical T-tail and spider slot system under investigation, the averages of the experimental values for the vertical and horizontal sections was on a par in accuracy with the individual readings. Thus the stress values for the difference and sum of the sections *D G E C* and *A F B H* were necessarily averaged together.

FIG. 12.



Isoclinics and principal stress lines of model.

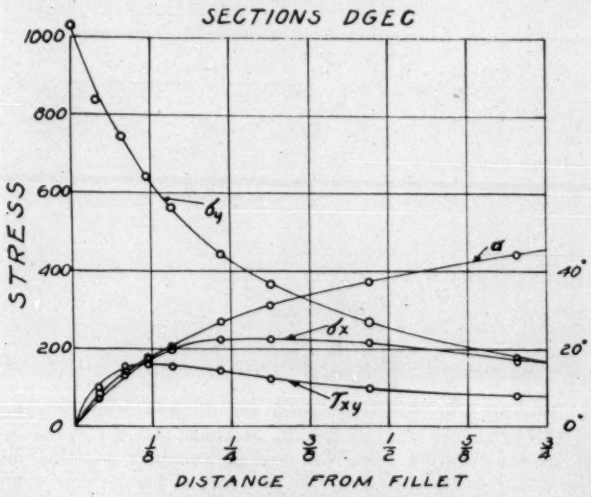
In Fig. 9 is plotted the sum and difference of the values of the principal stresses for the sections *D G E C*, indicated as $(p + q)$ and $(p - q)$; the principal stresses p and q; and the maximum shearing stress $(p - q)/2$. The similar values for the sections *A F B H* are given in Fig. 10.

The isoclinic photograph Fig. 11, depicting the location of the principal stresses having directions vertical and horizontal (0° isoclinic), is representive of the pictures taken

at 10° intervals to determine the directions of the principal stresses throughout the T-tail model. Fig. 12 is a summary of the data recorded from these pictures, and the corresponding locus of the principal stress lines in their respective directions.

From Fig. 12 it is observed that within the range of the points under considration the sections *A F B H* have principal stresses uniformly at about 45°. This would indicate that the maximum shear occurs in the plane of these sections, and the coördinate stresses in the *x*- and *y*-planes are of little importance. However, on sections *D G E C* the direction of the maximum shear is a function of the distance of the point from the fillet and the coördinate stresses were determined and plotted in Fig. 13.

FIG. 13.



Coördinate stresses and shear for sections *D G E C*.

A summary of the stresses obtained for the T-tail and the spider slot is given in Fig. 5.

CONCLUSIONS.

In Table I is given a summary of the maximum values of stress at the fillets of the sections as obtained photoelastically.

TABLE I.

Maximum Stresses, Pounds per Square Inch.

Sections.	*A F B H.*	*D G E C.*
$(p + q)$	− 612	1028
$(p - q)$	1840	1028
(p) tension	614	1028 (σy)
(q) compression	−1226	0
Maximum shear	920	

The calculation of the stresses in the T-tail by the conventional methods used in design offices would establish stresses for the sections as given in Table II.

TABLE II.

Stress Values, Pounds per Square Inch.

Sections.	*A F B H.*	*E C.*
Uniform compression, average	−633	
Bending tension, maximum	141	
Direct shear, average	172	
Combined shear, maximum	425	
Uniform tension, average		372

The multiplier of the maximum shearing stress by photoelastic observation over conventional calculation methods on sections *A F B H* is 2.16. For the tensile stress on the neck of the T-tail, sections *E C*, the ratio of the maximum over the average stress is 2.76. The first value above is a contact factor involving compression, bending and shear, and a comparison with equivalent conditions by other observers is not immediately available. However, it is the factor which determines the maximum stress in the structure and is therefore of greatest importance in the design. The second factor for the T-tail neck may be indirectly investigated. The *Design Data* assembled by Frocht [12] submits a stress concentration factor of 1.85 for invariant cases in tension or compression of fillets having an r/d value of 0.0735. Under

[12] "Design Data; Factors of Stress Concentration Photoelastically Determined," by M. M. Frocht, Trans. A. S. M. E., *Journal of Applied Mechanics*, 2, No. 2, June 1935, p. A-67.

similar conditions, a value of 2.4 is suggested by Dr. Timoshenko,[13] which indicates that this type of solution is not directly applicable. Referring again to Fig. 2, the tee-headed dove-tail joint investigated by Professor Coker,[14] the value given for the stress concentration at the fillet over the average stress is 2.08, with an r/d value of 0.138, and a partial dove-tail loading.

We might conclude that the limiting stress [15] for the ductile steel material in the pole punching and rotor spider occurs in shear at the fillets of the vertical sections. However, it is well known that before photoelastic investigations were instituted, extremely sharp or negligible fillets performed miraculous feats of strength. The fact remains that enlightenment on the distribution and intensity of stress in complex sections is an advantage and a benefit in design.

It would appear to be good practice to so arrange designs that the highest fillet stress accurately determined does not exceed the elastic limit of the material for the maximum loading condition.

ACKNOWLEDGMENT.

This problem was suggested by the Electric Machinery Manufacturing Company of Minneapolis, and the work was carried on through research funds from the Graduate School of the University of Minnesota.

[13] "Theory of Elasticity," by S. Timoshenko, Engineering Societies Monographs, McGraw-Hill Book Co., 1934, p. 132. See paper by E. E. Weibel, loc. cit., p. 5.

[14] See paper by E. G. Coker, loc. cit., p. 2.

[15] See "Theory of Elasticity," p. 344, loc. cit., p. 6.

THE STORY OF THE FRANKLIN INSTITUTE.

BY

SYDNEY L. WRIGHT, Ph.D.,

Associate Director, Medical Section and Director of Membership, The Franklin Institute.

III. RENEWED VIGOR.

The Franklin Institute was not immune to the inevitable changes and adjustments that marked the period following the World War. At first slowly and then more rapidly, it became evident that the Institute, true to its tradition, was to meet the new order with new service and renewed vigor.

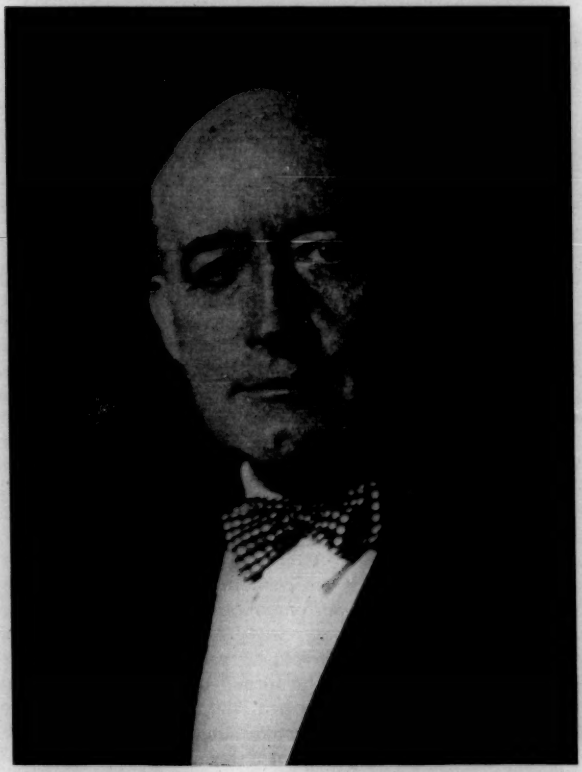
THE PERIOD OF ADJUSTMENT.

During the war, an important series of articles were published in the JOURNAL by Dr. W. J. Humphreys of the United States Weather Bureau. These were revised in 1920 by the author and published by the Institute in an octavo volume of 665 pages entitled "Physics of the Air." Special courses of lectures were presented in 1922 by F. W. Aston on "Atomic Weights and Isotopes" and in 1923 by Sir J. J. Thompson on "The Electron in Chemistry." These lectures were particularly appropriate as they dealt with the field in which it was planned to direct the activities of the Bartol Research Foundation, for the use of which funds had recently become available. It had been decided that after ninety-nine years of service the schools were to be discontinued, and the Institute was seeking a field of service more appropriate to the time.

In 1924 occurred the centennial of the Institute which was celebrated by noteworthy exercises extending over three days. Formal conferences of a scientific nature, lectures by distinguished scientists, and the formal opening of the Bartol Research Laboratories furnished the chief scientific fare. The final centenary dinner brought together what was probably the most distinguished gathering of scientists from all over the world that had met in America. The exercises marked the first year of the presidency of William C. L. Eglin,

successor of Walton Clark who had held that office for seventeen years.

The following year Dr. Howard McClenahan was chosen to serve as Secretary of The Franklin Institute. This decision was a momentous one, for the former Dean of Princeton



HOWARD MCCLENAHAN 1872–1935.

Secretary and Director of The Franklin Institute. Editor of the JOURNAL of The Franklin Institute.

University possessed just those qualities of mind and personality which were most needed by the Institute at the time. Because of his long association with Princeton, and the notable work he had done there both as professor and adminstrator, he was recognized as one of the leading educators of the country. For many years he had been Professor of

Philadelphia Inquirer.

AT THE FORMAL OPENING OF THE AVIATION SECTION.

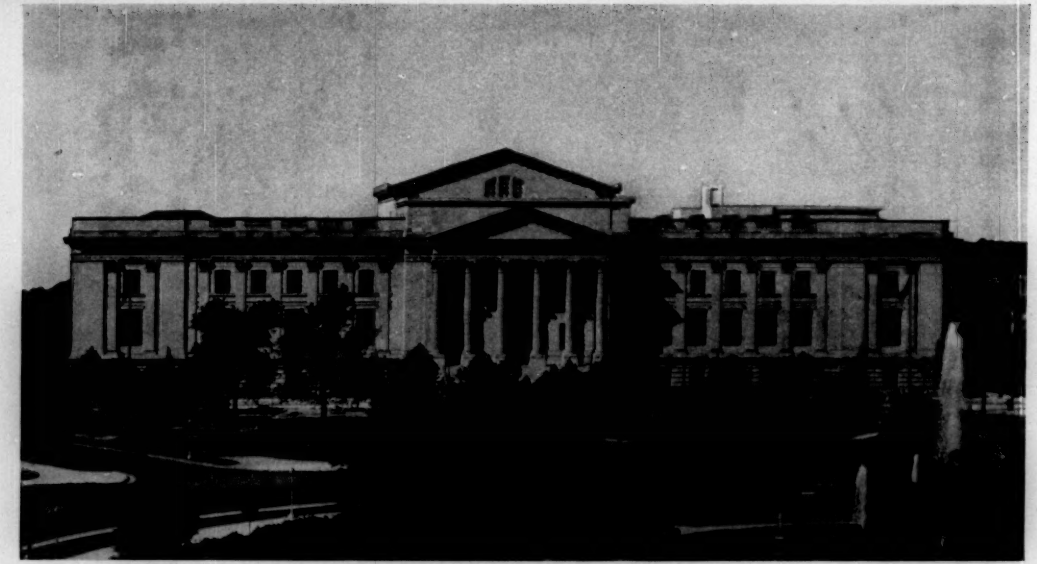
Orville Wright and Amelia Earhart Putnam, standing under the plane used by the latter in her Trans-Atlantic flight. An early Wright airplane is a feature of this exhibit.

Physics and for thirteen years had served as Dean of the College. His sound learning, fearlessness and insight made him respected and admired; his patience, understanding, sense of fair play and humor had endeared him to many. By broad acquaintance with the scientific world, by reputation, experience and native gifts, he was exceptionally well equipped for the new endeavor.

The effect of this appointment became noticeable promptly. In his first year he established Medal Day—the occasion when the Institute presents awards for achievement and does honor to the recipients of the medals. The James Mapes Dodge Lecture Foundation was established under his guidance, the JOURNAL was given new form and broader content, The Bartol Research Foundation was put upon a sound scientific basis, the scope of the weekly lectures was widened and by reason of his wide acquaintance he was able to summon many persons of distinction to talk in the Hall of the Institute.

For many years The Franklin Institute had looked forward to the erection of a new building to replace the one erected in the year of its incorporation and now long outgrown. Since 1906 there had been in existence a committee to prepare plans and to care for the funds contributed for the purpose. The original three members of this committee, James M. Dodge, Alfred C. Harrison and Henry Howson were instrumental in securing for The Franklin Institute the fund left by Benjamin Franklin in his will to the City of Philadelphia. The Institute raised an equal sum from its members and friends and the entire amount was left with the Board of City Trusts until it should be needed for the erection of the new building. With the purpose of the fund ever in mind, the Institute held title in the ensuing years to several sites considered suitable for the purpose. The funds were so well handled that when the committee was discharged, Mr. Howson, the only survivor of the original committee, was able to turn over to the Institute cash and property on which were realized over 1½ millions of dollars. The Franklin Fund which was the cause of the formation of this committee amounted to $125,000.

The activities of the Institute at this time centered largely about the library, the lectures, the JOURNAL, and the awards of the Committee on Science and the Arts. The library had grown until it served as a standard for scientific libraries. Not only was it probably the most complete of the special libraries in its field, but the quiet and studious atmosphere of the reading room were conducive to effective work. The willing helpfulness, wide knowledge of scientific literature



Gladys Müller.

"In Honor of Benjamin Franklin."

The new building viewed from across Logan Square. The flight of steps leads directly to the Franklin Memorial Hall.
This was one of the last great buildings designed by the late John T. Windrim, Architect.

and keen memory of the librarian, Alfred Rigling, was of service to student and expert alike.

The Committee on Science and the Arts continued to study and appraise the work of scientists. Its activities became centered upon Medal Day and its labors in this period were increased by the addition of four new medals to be awarded.

Gladys Müller.

PEPPER HALL.

The reading room of the Library. Through the doorway is the Members Room in which the patent records of several countries are preserved.

The Louis E. Levy Medal was established by the children of Louis E. Levy and is awarded for papers contributed to the JOURNAL of the Institute, descriptive of the author's researches. It was first awarded in 1924. W. D. Coolidge, Harvey Fletcher, H. C. Hayes, L. J. R. Holst and Inge Lyse have been among the recipients.

The George R. Henderson Medal was established by Virginia P. C. Henderson in memory of her husband for meritorious inventions or discoveries in the field of railway

engineering. Otto C. Duryea, Rupen Eksergian, W. F. Kiesel, Jr., and A. N. Talbot have been among those to whom it has been awarded since 1928.

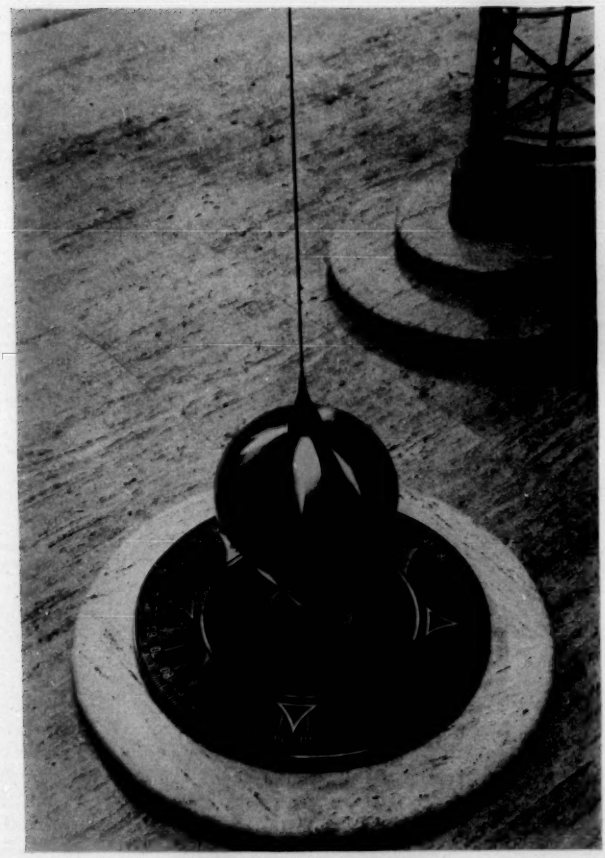
The Walton Clark Medal was established by the United Gas Improvement Company of Philadelphia in honor of its vice-president, who had also been president of The Franklin Institute. Offered for original and notable work in the gas industry, it was first awarded to Dr. Clark. The most recent award was to Joseph Becker.

The John Price Wetherill Medal has been awarded since 1926 for discovery or invention in physical sciences or for new and important combinations of principles or methods already known. It was established by the family of Mr. Wetherill and has been awarded, among others, to Carl Akeley, E. N. Harvey, W. N. Jennings, H. S. Hulbert, F. C. and R. R. McMath, William H. Mason, C. G. Munters and B. C. Von Platen, F. E. Ross, and H. E. Warren.

THE PERIOD OF PREPARATION.

Despite the vigorous manner in which the Institute was carrying on its ancient activities and its value to young students of science, Dr. McClenahan was quick to sense the diminution of youthful interest which followed the closing of the schools and which could not be recaptured in its entirety by the brief lecture series furnished under the Dodge Foundation. As early as 1922 the Board had planned the erection of a technological museum such as had been developed in Europe, but was not generally known in this country. These plans promised to fulfill the need felt by the Dean, as he was affectionately called, and being convinced of the educational value of such a museum, he became their champion. He presented his views to the Board of Managers and obtained authority to study at first hand the museums of London, Paris and Munich. Upon his return, he presented the project for a museum of this type with such interest and enthusiasm that he was accorded the whole-hearted support of the Board.

At the dinner of the Poor Richard Club held on Franklin's birthday in 1927, Mr. Morton Gibbons-Neff, the president of that organization, suggested that there should be in Philadelphia a national monument in honor of Benjamin Franklin.

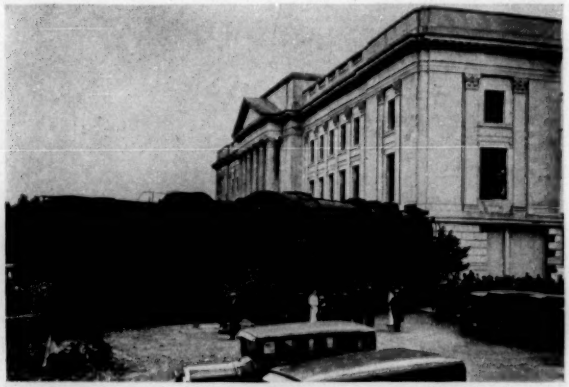


Gladys Muller.

THE FOUCAULT PENDULUM.

This pendulum, the gift of Mr. and Mrs. Richard L. Binder, is similar to the famous pendulum which was suspended from the dome of the Pantheon in Paris. In his study of the pendulum Leon Foucault in 1851 devised the first terrestrial instrument for showing the rotation of the earth.

It was considered desirable that this should be located on the Parkway. A number of meetings were held in which The Franklin Institute was invited to participate. It was the consensus of opinion that the memorial should be not merely a monument of stone, but should be the center of a useful activity that would be a living memorial to the great man. To achieve this purpose the coöperation of a great scientific society was essential. To obtain the necessary coöperation and to raise funds for the memorial, the Poor Richard



Philadelphia Record.

THE ARRIVAL OF NUMBER 60,000.

The answer to a frequent question. The great Baldwin locomotive was pulled into the building through a hole left in the wall. A large cradle distributed the load to avoid injury to the streets over which it was moved.

Club formed The Benjamin Franklin Memorial, Inc. Cyrus H. K. Curtis was elected president of the new corporation and many of the leading citizens of the community served on its Board. Mr. Curtis, New England born, had come, like Franklin, to Philadelphia as a young man and entered the publishing business.

The Franklin Institute was already planning to erect, on the Parkway, a building to house an industrial museum which would be well adapted to serve as such a living memorial.

Coöperation between two organizations which had independently arrived at such similar plans was obviously to their mutual advantage. A working agreement was speedily arranged between the Institute and The Benjamin Franklin Memorial, under which the latter agreed to raise the necessary funds, and the former to use those funds for the erection, equipment and operation of the new museum. Although the entire building and its manifold activities would all be in

Gladys Müller.

A PORTION OF THE LIGHTING EXHIBITS.

Sections of rooms, appropriately furnished show the development of home lighting from the first settlement in this country.

honor of Benjamin Franklin, it was provided that the building should contain a tangible memorial and a museum of the graphic arts.

Plans were laid carefully. The proposal met with enormous popular approval. Despite the financial crash of November 1929 it was decided to raise the funds in the spring of the following year. Mr. Curtis by the example of his generosity and by his contagious enthusiasm, proved a tower

of strength. Nearly a thousand interested citizens labored faithfully, and the sum of over $5,100,000 was pledged in twelve days by more than 11 thousand subscribers. Besides gifts of money, many offers of historic exhibits were received from all over the country and industrial concerns, appreciative of what the Institute had done for industry and planned to do, offered to aid in the preparation of exhibits.

The City of Philadelphia granted the use of a plot of land on the Parkway larger and more suitable than that owned by the Institute, for a nominal rental. There, on June 18, 1930, which was the eightieth birthday of Mr. Curtis, the work of excavation was actually commenced. The first soil was removed by Mr. Curtis as President of the Benjamin Franklin Memorial.

For most people the knowledge that the necessary funds had been promised, was an assurance that in due course a great museum would arise. That faith in The Franklin Institute was justified but, for the officers of the Institute, the intervening time was a period of great and exhausting effort and of heavy responsibility. The president, Nathan Hayward, who had taken office in 1929, the chairmen and members of the various committees of the Board and other interested persons, gave freely of their time and energy and through their combined efforts the great task was accomplished. Dr. McClenahan was named Director of the new museum, and almost all actions of importance received his consideration either in that capacity or as Secretary. The Controller, William F. Jackson, Jr., had greatly increased responsibility and also, as Business Manager, was in constant consultation with Dr. McClenahan and members of the various committees.

Detailed building plans were made. It was decided to construct about half the building which will ultimately be erected. The central section to the east was designed to house the tangible memorial, an heroic statue of Benjamin Franklin contributed by William L. McLean and now nearing completion at the hands of the sculptor James Earle Fraser. In the hallway leading to the memorial chamber are tablets commemorating the services of the Poor Richard Club in establishing the Benjamin Franklin Memorial Incorporated

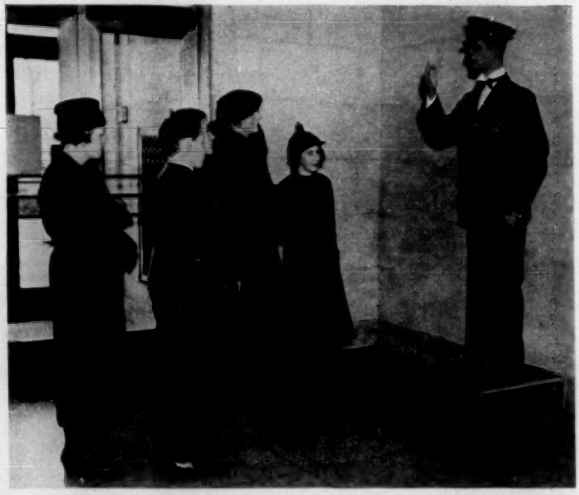
Evening Ledger.

AN AUSPICIOUS BEGINNING.

Mr. Cyrus H. K. Curtis starting the excavation for the new building while Dr. McClenahan indicates his pleasure at the actual commencement of work.

and doing honor to Cyrus H. K. Curtis whose generosity and personal effort assured the success of the venture.

Flanking the entrance hallway on either side were planned the Halls of Graphic Arts and of Electrical Communications. These halls feature the industries closest to Franklin's heart and were made possible through the munificence of Mr. and Mrs. A. Atwater Kent and Mr. and Mrs. George H. Lorimer



Gladys Müller.

THE ROBOT.

An invariable source of interest and amusement. Each visitor on entering passes through a beam of light directed on a photoelectric cell and as the robot is approached it raises its hand to its forehead and extends a polite greeting.

respectively. Throughout the museum there are other halls that were the gifts of other contributors of large sums.

The central section to the north was allotted to the Fels Planetarium, the gift of Samuel S. Fels who desired that Philadelphia should have a planetarium and who, when the plans of the Institute became known, immediately offered it to that organization. The Library was placed adjacent to the

planetarium, on the second floor, and the space surrounding the dome of the planetarium was used for book stacks. The reading room was named Pepper Hall as a token of appreciation of the great help and the splendid leadership given by George Wharton Pepper, former United States Senator, who had served as chairman during the campaign for funds.

Evening Ledger.

THE FELS PLANETARIUM.

Mr. Samuel S. Fels, the donor of the instrument, examines it with Mr. Stokley soon after its installation.

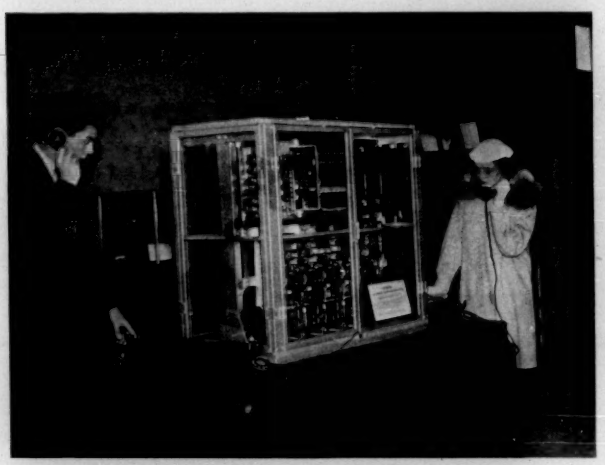
The scientific staff was gradually assembled and proceeded to develop plans for the special sections in their charge. Dr. James Barnes was appointed to the Physics Section, Charles E. Bonine to the Sections of Engineering and Transportation, Russell L. Davis to Graphic Arts, Dr. Nicol H. Smith to Chemistry, and C. Townsend Ludington to Aviation. James

Stokley was named Director of the Fels Planetarium and had charge of the Astronomical Section. These were among the first of a considerable group of specialists in various fields who devoted their time to planning, securing, arranging and constructing exhibits with the aid of the drafting room and an excellent model and instrument making shop in which were a skillful and intelligent group of workers. These men with their colleagues and assistants were the ones who, under the guidance of Dr. McClenahan, really equipped The Franklin Institute as it appeared when first shown to the public.

The Planetarium was finally opened on November 6, 1933, after a formal presentation and several demonstrations before invited groups of distinguished scientists and citizens of Philadelphia. The Museum was opened on January 1, 1934. The element of time, and the desire that each section should be a credit to the Institute and to the particular science or industry on display, prevented it from being completed at that time. Some sections have not yet been opened and others are open, but are awaiting further funds for their complete development. As funds for the erection of the remainder of the building become available it will be possible to increase the number of fields of science and industry illustrated, and to make a more satisfactory display of some which are now inadequately presented.

The press and the public were loud in their expressions of approval of the display and of the manner in which it was presented. The feature which aroused the most enthusiasm was the opportunity offered to the visitors to operate a machine or perform an experiment repeatedly until it was understood. Of necessity some exhibits were more frail than others, but all were designed for constant usage. Exhibits of an historial interest were, of course, adequately protected from abuse. The more delicate ones were placed behind glass, but the sturdier were placed where they could be seen to best advantage. During the first year of operation 279,000 visitors attended the demonstrations in the Planetarium, 262,000 visited the Museum. Special demonstrations for school children were held in the Planetarium in which the language used and the principles presented were adapted for the understanding of those of school age.

An admission charge of 25¢ was made for visitors to the Museum and a similar charge for the Planetarium. It was felt that this small charge would serve not only as a source of revenue, but would eliminate the idly curious and encourage an appreciation of the fact that the preparation and operation of Museums are an expense that must be met in some way by the public. In many museums this is managed by taxation, but the Institute receives no support from taxation and the



Gladys Müller.

THE AUTOMATIC TELEPHONE.

A miniature telephone exchange with four telephones. Calls may be made from one to another and the mechanism observed through the glass case.

grants that have been made in the past have been for expenses incurred for special services performed. The small admission charge has proved useful in an unexpected way, for it has kept the staff keenly aware of the directions of public interest and alert to serve that interest as well as possible within the field of science. Children from schools within the city are admitted free of charge, and about 100,000 take advantage annually of this privilege. For schools outside the city a

discount of 40 per cent. is allowed. Students may obtain these tickets at their respective schools for their individual use, although more frequently they are accompanied by a teacher who brings them to see particular sections of the Museum.

Members of the Institute are entitled to unlimited free admission to the Museum and Planetarium. Special classes of membership have been provided for those who wished to use or support these activities, but who had no particular

THE ELECTRIC SPARK.

Receiving a slight electric shock is the source of as much interest and amusement now as it was a hundred years ago.

desire to use the more technical activities such as the Library and the JOURNAL. Thousands of citizens have taken advantage of these memberships. The revenue derived from membership dues and gate receipts provide for almost half the annual expenses of the Institute's activities on the Parkway.

It was a time of satisfaction for the Institute and of great personal triumph for the Dean. Honors of many kinds were offered him. He was elected to the Board of Directors of the Deutsches Museum in Munich. He was privileged as are few

men, to view in being the realization of a dream come true. He had labored well and the result was visible to all.

In the midst of planning and building, the other functions of the Institute continued as before or with greater vigor. The Library was in constant use, the JOURNAL appeared regularly, medals were awarded and distinguished lecturers continued to come to Philadelphia and talk to the members and guests of The Franklin Institute. When the new building opened, there was merely a change of scene and greater facilities for the effective operation of these activities.

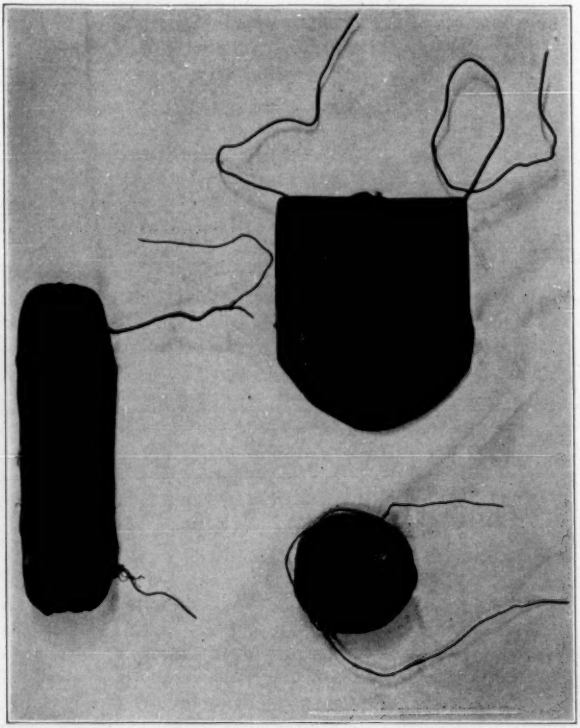
Dr. McClenahan's health began to fail him and it was necessary for him to conserve his strength. He had given tirelessly of his energy for several years, his keen humor and appreciation of all good things never left him, but in May 1935 illness forced him to abandon his work entirely in an effort to regain his health. He died on December 17th of that year.

Several months before Dr. McClenahan's death it became doubtful that he would ever be able to continue the double duties of Secretary and Director of the Museum. Continuing as Secretary of The Franklin Institute, he was relieved of the more pressing executive duties of Director by the appointment to that post in October 1935 of Henry Butler Allen.

Mr. Allen assumed his office well equipped to continue the liaison which had always existed between the Institute and industry. He was with Henry Disston & Sons, Inc., as chief metallurgist at the time of his appointment. He had been closely associated with the Committee on Science and the Arts since 1917, at one time its chairman, and had been chairman of the Committee on Museum of the Board of Managers since 1933, so that he was already familiar with many of the problems which confronted him. A definite program was adopted with the purpose of increasing the use of the Museum by the public and thereby increasing the usefulness of the Museum. Special shows of timely interest in which scientific discoveries and principles were dramatized and the preparation of some of these for display elsewhere under the auspices of the Institute were features of this program.

The Institute today is an organization of national and international importance, which is devoted to public educa-

tion and the advancement of science and industry. These ends are achieved through a multitude of activities taking place in or directed from the great building on the Parkway in Philadelphia constructed in honor of Benjamin Franklin. The scope and purpose of many of these activities have been indicated in this brief story. Many of them have been con-



FARADAYS COILS.

These coils made by Michael Faraday, were presented to The Franklin Institute by the Royal Institution of Great Britain in 1927.

tinuously carried on for more than a century. A number, once important, have been abandoned when their usefulness was out-lived, and many are the result of the new opportunity for service created by the new Museum and Planetarium. A brief account of the present organization and activities of the Institute is being prepared.

[*The fourth and final article on "The Story of The Franklin Institute" will appear in the July number of the Journal.*]

GRAPHICAL ANALYSIS OF TRANSIENT PHENOMENA IN LINEAR FLOW.

BY

KALMAN J. DeJUHASZ,

Associate Professor of Engineering Research, The Pennsylvania State College.

(*Concluded from May issue*)

9. Pump, Pipe, Storer and Nozzle (Figs. 29*a*, *b*, 30*a*, *b*).

The phenomena are dependent on the order of sequence in which the elements are arranged, i.e., on whether the storer is adjoining the pump or the nozzle. Both arrangements are used (either intentionally or incidentally) in fuel injection. Therefore both cases will be treated.

(*a*) *Storer adjoining Pump* (*Figs. 29a, b*). In the v–p diagram the pump is represented by the v_P = const. line, the storer by its direction tangent: $\tan \beta = kFL/aR$, the pipe by its direction tangent: $\tan \alpha = k/a$, and the nozzle by the efflux parabola v_N. All velocities are reduced to the same cross-sectional area, i.e.:

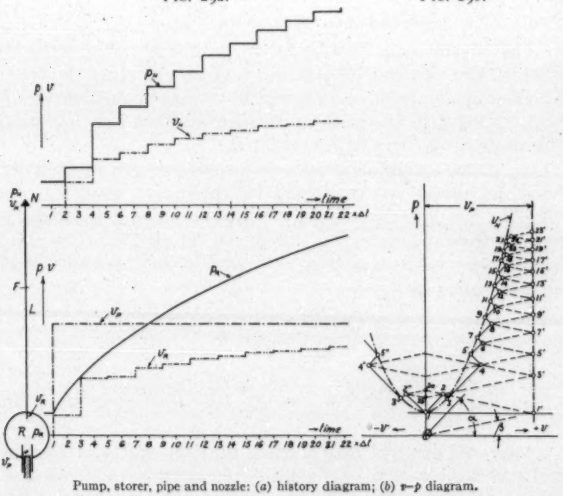
$$v_P = \frac{\text{Volume rate of pump delivery}}{F},$$

$$v_N = \frac{\text{Volume rate of nozzle discharge}}{F}.$$

After the pump began feeding into the storer at the end of the first interval the pressure in the latter rises to point *2a*. During the same time the influx into the pipe takes place according to successive points on the *1–2″* line with a corresponding lowering of pressure in the storer according to the *2a–2″* line. According to our previously explained method of simplification we will assume that the mean values of pressure and velocity, corresponding to point *2″* prevail during the first and second intervals in the storer and at its junction with the pipe. This point *2″* is determined as the intersection of the *1–2″* line (change of flow condition at the storer end of the pipe) and of the *2a–2″* line (change of pressure in the

storer owing to efflux into the pipe). In the second interval owing to the efflux from the storer into the pipe a further drop of pressure takes place from $2''$ to $2b$ but also, owing to the inflow from the pump a pressure rise takes place from $2b$ to $3'$ this being the resultant final storer-pressure after the second interval. During the first and second interval inflow takes place from the storer into the pipe with the mean pressure and velocity corresponding to point $2''$. As this wave

FIG. 29a. FIG. 29b.



Pump, storer, pipe and nozzle: (*a*) history diagram; (*b*) v–p diagram.

reaches the nozzle end of the pipe a drop of pressure and increase of velocity takes place according to point $3''$ situated on the efflux parabola.

It is not necessary, however, to draw the efflux parabola on the negative side of the point of origin O. The construction can be performed, with some gain in simplification, on the parabola drawn on the positive side of the origin. Doing this the points 2 and 3 are obtained which are symmetrical to the points $2''$ and $3''$ previously obtained, and equivalent

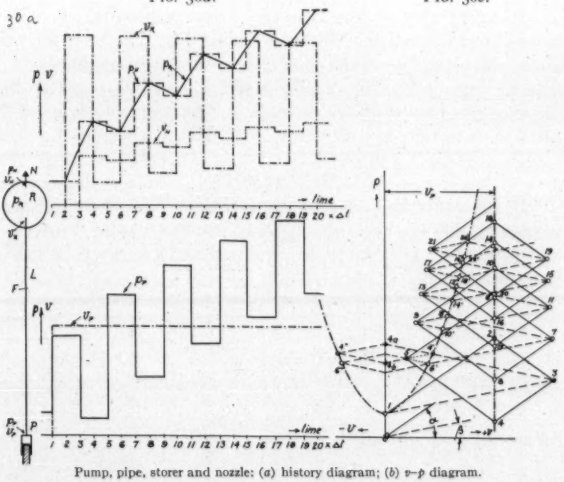
to them as far as the pressure and absolute value of velocity are concerned. Continuing this method of construction three series of points are obtained in the v–p diagram:

(I) $1'$–2–$3'$–4–$5'$–6–$7'$ ···, defining the change of pressure in the storer;

(II) 2–4–6–8–10 ···, defining the pressure and velocity at the storer-end of the pipe;

(III) 1–3–5–7–9–···, defining the pressure and velocity at the nozzle-end of the pipe.

FIG. 30*a*. FIG. 30*b*.



Pump, pipe, storer and nozzle: (*a*) history diagram; (*b*) v–p diagram.

The pressure and velocity values corresponding to these points have been transferred into the history diagram as shown in Fig. 29*a*.

Compared with the Pump-Pipe-Nozzle combination (Figs. 10*a*, *b*) it is seen that the insertion of the storer after the pump decreases the rate of nozzle-discharge and extends its duration.

(*b*) *Storer adjoining Nozzle* (*Figs. 30a, b*). Similar definitions and notations are used as in the previous example; the

graphical analysis is also analogous to the former case, and its detailed explanation can be omitted. The following three series of points are obtained in the v–p diagram:

(I) 2–4–6–8–10–12–⋯, defining the pressure and velocity at the pump-end of the pipe;

(II) 3–5–7–9–11–⋯, defining the pressure and velocity at the storer-end of the pipe;

(III) 4′–6′–8′–10′–12′–14′–⋯, defining the pressure and velocity (reduced to the common F cross-section) at the nozzle.

Plotting these values in the history diagram it will be noted that in contrast to the previous example both the pressure and velocity values show a non-monotonous increase, an alternating cycle of increase and decrease being superimposed on the general trend of increase. The characteristic of the outflow is noticeably different from that in the previous case.

10. Swinger and Pipe.

If the hydraulic system comprises a pipe then it is convenient to choose the time-element Δt equal to the "interval" of the pipe: L/a. Applying this value to Eq. 14, it can be written

$$\frac{p_2 - p_1}{\Delta v} = \frac{M}{F}\frac{a}{L}, \tag{19}$$

substituting $a = \frac{a^2}{a} = \frac{kV_0}{a}$ and with some mathematical transformations we obtain:

$$\frac{p_2 - p_1}{v_2 - v_1} = \frac{k}{a}\frac{M}{\left(\frac{FL}{V_0}\right)} = G = \tan\gamma, \tag{20}$$

FL/V_0 being the mass of liquid in the pipe.

Assuming that the direction of displacement is vertical, i.e., that the swinger is acted upon by its own weight which is balanced statically by a fluid pressure p_0,

$$Mg = Fp_0,$$

our equation will take the following form:

$$\frac{p - p_0}{v_2 - v_1} = \frac{k}{a}\frac{M}{\left(\frac{FL}{V_0}\right)} = G. \qquad (21)$$

If there is no swinger, $M = 0$; $\gamma = 0$, the phenomenon is identical with the discharging into an infinite storer having $p_1 = 0$ pressure. If the mass of swinger is equal to the mass of the liquid column,

$$M = \frac{FL}{V_0}, \qquad \text{then: } \gamma = \alpha,$$

the resulting mean velocity will be equal to that corresponding to the pressure wave and there will be no reflection. If the swinger has an infinite mass, $M = \infty$, then $\gamma = 90°$, the case will be identical with that of a closed pipe.

A number of examples will be given to illustrate the graphical method of analysis of this combination.

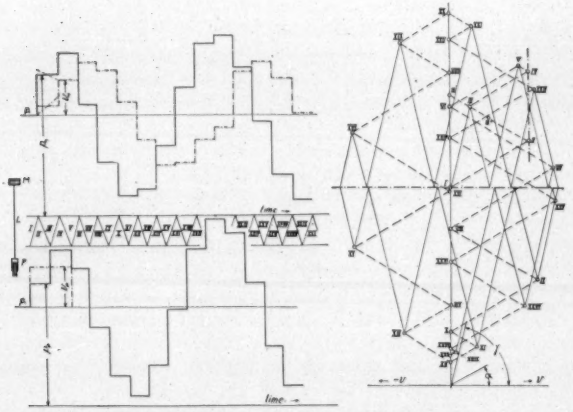
11. Pump, Pipe and Swinger (Figs. 31*a*, *b*).

The pump P delivers liquid through a pipe of L length and F cross-sectional area, during 4 intervals L/a with a constant v_P velocity of delivery, against the swinger M which is originally at rest. Starting, in the v–p diagram, from the point I ($p = p_1$, $v = 0$), the velocity v_P is imparted by the pump to the liquid and the state II is attained. When this wave reaches the swinger at the end of the first interval it will be reflected according to state III'. The pressure, however, imparts momentum to the swinger, and consequently, as it gathers speed, the liquid adjacent to its cross-sectional area loses pressure and passes through the consecutive stages III'–III–III''. Therefore, at the swinger-end of the pipe both the pressure and velocity will change during the second and third intervals, somewhat according to the sloping lines shown on the time-diagram. In order to simplify our analysis we shall consider the mean values existing throughout the second and third intervals corresponding to point III, defined as the intersection of line II–III (representing the change of state in the pipe) and of line I–III (representing the change of

velocity at the swinger-end, during one interval, as a function of pressure). When the wave reaches the pump its velocity is restored again to the v_P value (Point *IV*) and this wave, in turn, on reaching the swinger-end attains the condition *V*.

When wave *V* reaches the pump-end of the pipe the delivery ceases and the velocity is reduced to zero (Point *VI*). The pressure in the pipe being still greater than the equilibrium pressure p_1 the swinger's velocity is still increasing when the wave *VI* reaches it and the condition *VII* is attained.

FIG. 31*a*. FIG. 31*b*.



Pump, pipe and swinger: (*a*) history diagram; (*b*), v–p diagram.

Repeating this procedure the points *VIII*, *IX* · · · *XXX* can be determined and the corresponding v and p values transferred into the time-diagram as shown in Fig. 31*a*.

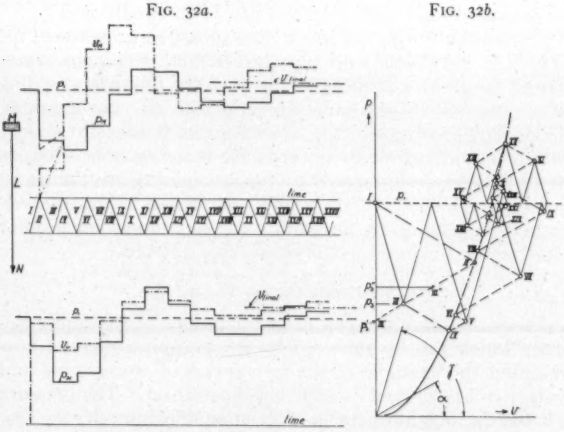
It is seen that the velocity and pressure values oscillate above and below their mean ($p = p_1$, $v = 0$) values in an approximately harmonic fashion, the velocity values following the pressure values with a quarter period difference in phase, i.e., the velocity is greatest when the $p - p_1$ value is zero, and vice versa. This tendency towards harmonic variation is clearly discernible also from the v–p diagram, as the locus

of values corresponding to the state of liquid at the swinger-end (Points V, VI, IX, XI, $\cdots$ $XXIX$) is approximately an ellipse.

12. Swinger, Pipe and Nozzle (Figs. 32*a*, *b*.)

Initially the liquid column is at rest at a pressure p_1 corresponding to the static load of the swinger. At the beginning of our time-reckoning the "open" type of nozzle is instantaneously opened to its full area and the wave II is initiated at the nozzle. As the swinger is at rest this wave II on

FIG. 32*a*. FIG. 32*b*.



Swinger, pipe and nozzle: (*a*) history diagram; (*b*) v–p diagram.

reaching the swinger-end is reflected (III') towards the nozzle and momentarily a pressure difference $p_1 - p_3'$ acts upon the swinger and imparts velocity to it. As a consequence, this velocity-increasing pressure-difference diminishes and at the end of the second interval becomes $p_1 - p_3$ and at the end of the third interval $p_1 - p_3''$. Thus, during the second and third intervals the velocity and also the pressure at the swinger-end is changing, from values III' to values III''. In order to simplify our reasoning we consider the swinger acted upon, during the second and third intervals, by a constant

state of liquid, corresponding to the mean value *III*. This point *III* is the intersection of the line *II–III'* (representing the change of state in the column) and of the line *I–III* (representing the increase of velocity of the swinger under a mean pressure-difference $p_1 - p_3$ during one interval L/a). During these two intervals the velocity of the swinger has increased to the double value of v_3. At the nozzle a new wave *IV* is originated which reaches the swinger-end. Owing to the difference of velocity between the liquid and the swinger, a wave *V* is originated at the swinger which is reflected towards the nozzle and produces flow with condition *VI*.

Continuing this procedure the subsequent points *VII*, *VIII*, *IX*, $\cdots$ *XXVI* are obtained in the v–p diagram representing the mean condition of the liquid in the corresponding zones (denoted by the same numerals) in the time-diagram. Plotting these values in the time-diagram it is seen that the state of liquid converges towards the state corresponding to the static pressure produced by the swinger, and to the corresponding velocity on the efflux parabola. This state is reached, in general, by an infinite series of steps which differ from the final values by ever-decreasing amounts.

13. Storer, Pipe and Swinger (Figs. 33*a*, *b*).

From the large number of combinations of hydraulic elements which can be analyzed by the graphical method now presented the example of the interaction of storer, pipe and swinger will be offered as a further illustration. The pressure p_0 holds the weight of the swinger in equilibrium: $Mg = Fp_0$. Before our beginning of time-reckoning an extra force, acting on the swinger, keeps the pressure at the p_1 value (point *I*). At the beginning of our time-reckoning this extra force is suddenly removed. The pressure-difference $p_1 - p_0$ imparts velocity to the swinger, and the resulting expansion, in turn, brings about a reduction of pressure in the liquid according to line *I–II*. At the end of the first interval the condition *II* is reached and in order to simplify our reasoning we shall assume this condition *II* as holding good for the duration of the first and second intervals. The point *II* is, as it was shown before, defined as the intersection of line *I–II* (representing the change of state in the pipe) and of the line $p_0 - II$

(representing the change of velocity of the swinger during one L/a interval, by a pressure-difference $p - p_0$).

The construction is clearly shown in Fig. 33*b*. It is seen that the even-numbered points representing the state at the swinger-end of the pipe lie on an ellipse, and the odd-numbered points representing the state at the swinger-end of the pipe lie on another ellipse. Consequently, the velocity values follow the pressure values with a phase-difference of one quarter period.

14. Storer and Swinger (Figs. 34*a*, *b*).

In order to adduce proof of the validity of the graphical procedure, both the mathematical and the graphical method will be applied to one and the same problem. If, then, both yield the same result it can be taken as so to speak an experimental demonstration of the correctness of the graphical analysis. As such a test case will be chosen the combination is storer and swinger. Into the storer of R volume enters the plunger of F area loaded by a swinger of M mass. In

FIG. 33*a*.

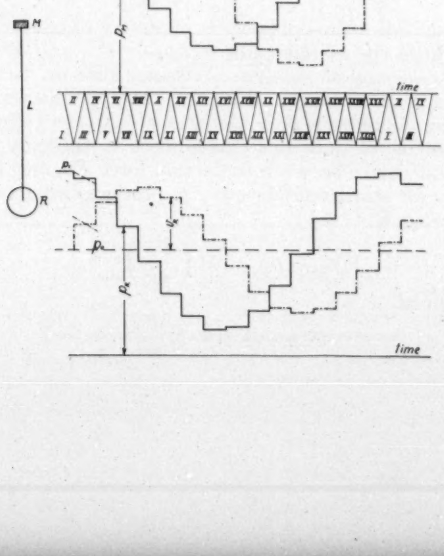
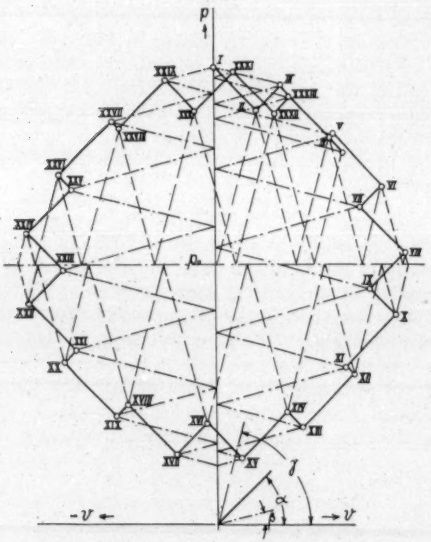


FIG. 33b.



Storer, pipe and swinger: (*a*) history diagram; (*b*) v–p diagram.

static equilibrium a p_0 pressure is necessary to counterbalance the weight of the swinger: $Mg = Fp_0$.

(*a*) *Mathematical Analysis.* Assume that an excess force is applied on the swinger, displacing it by the distance x_1 and generating a pressure p_1 in the storer. At the beginning of our reckoning of time this excess force is suddenly released and the difference between the actual force Fp_1 and the force necessary for static equilibrium Fp_0 produces an acceleration on the swinger,

$$F(p_1 - p_0) = M\left(\frac{d^2x}{dt^2}\right)_{x=x_1}, \qquad (22)$$

or, in general,

$$F(p - p_0) = M\frac{d^2x}{dt^2}. \qquad (23)$$

FIG. 34*a*.

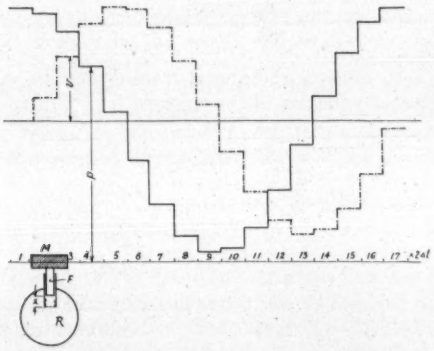
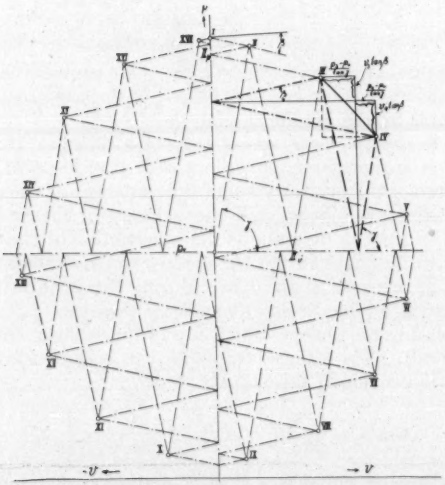


FIG. 34*b*.



Storer and swinger: (*a*) history diagram; (*b*) *v*–*p* diagram.

On the other hand,

$$\frac{Fx}{R} = \frac{p - p_0}{k},$$

whence, with some mathematical transformations we obtain the differential equation of the motion:

$$\frac{d^2x}{dt^2} = -\frac{kF^2}{RM}x. \tag{24}$$

The solution of this equation is:

$$x = (p_1 - p_0)\frac{R}{kF}\cos\sqrt{\frac{kF^2}{RM}}t. \tag{25}$$

We want to express the interrelationship of pressure and velocity, i.e.: $(p - p_0)$ and $v = dx/dt$. Eliminating the variable time we obtain:

$$\frac{(p - p_0)^2}{(p_1 - p_0)^2} + \frac{v^2}{(p_1 - p_0)^2\frac{R}{kM}} = 1, \tag{25}$$

which is the equation of an ellipse. Our problem is now to establish whether or not this ellipse is the same as the one obtainable by the graphical analysis.

(*b*) *Graphical Analysis.* In the v–p diagram the initial condition is represented by the $v = 0$, $p = p_1$ point. After the elapse of the arbitrary small time-interval Δt the pressure in the storer will be p_2 and the velocity of the swinger v_2, defined in the v–p diagram as the intersection of the straight line drawn at angle β from the $(p_1, 0)$ point (representing the change of pressure in the storer during the Δt interval) and of the straight line drawn at angle γ from the $(p_0, 0)$ point (representing the change of velocity of the swinger during the Δt interval). The values of β and γ can be found from Eqs. 13 and 14 previously developed:

$$\tan\beta = \frac{kF}{R}\Delta t \qquad \text{and} \qquad \frac{1}{\tan\gamma} = \frac{F}{M}\Delta t$$

by substituting the values k, F, R and M, and assuming an arbitrary, small time-interval Δt. This condition v_2p_2 is as-

sumed to hold good, as a mean value, during the first two intervals. At the end of the second interval the total decrease of pressure in the storer will be $[2(p_2 - p_0)]/\tan\gamma$ and the total increase of velocity of the swinger will be $2v_2 \tan\beta$ as denoted by points II_v and II_p in the diagram. The mean value of the pressure and of the velocity as defined by point *III* for the third and fourth intervals will be found in a similar manner, as the intersection of the line drawn at angle β from the II_p point and of the line drawn at angle γ from the II_v point. Continuing this method of construction from each point i the subsequent point $i + 1$ can be determined. In Fig. 34*b* this construction is carried through points *I, II, III,* $\cdots$ *XVII* and on a first inspection it is apparent that the locus of these points is an ellipse-like figure. It remains to be proven whether this ellipse is identical with the *v–p* ellipse previously found by the mathematical analysis. From the method of construction it follows:

$$\begin{aligned} -p_{i+1} + p_i &= (v_{i+1} + v_i)\tan\beta = -\Delta p, \\ v_{i+1} - v_i &= (p_{i+1} + p_i - 2p_0)\frac{1}{\tan\gamma} = \Delta v. \end{aligned} \tag{26}$$

Hence it can be written:

$$\frac{\Delta p}{\Delta v} = -\frac{v_{i+1} + v_i}{p_{i+1} + p_i - 2p_0}\tan\beta\tan\gamma$$

$$= -\frac{v_{i+1} + v_i}{p_{i+1} + p_i - 2p_0}\frac{Mk}{R}. \tag{27}$$

Approximating Δt to 0, $\Delta p/\Delta v$ will become dp/dv and

$$\frac{v_{i+1} + v_i}{p_{i+1} + p_i - 2p_0} = \frac{2v}{2(p - p_0)}.$$

It can be written:

$$\frac{dp}{dv} = -\frac{v}{p - p_0}\frac{Mk}{R}. \tag{28}$$

as the differential equation of the curve to which the locus of the points obtained by our construction converges when the arbitrary time-interval Δt is made to approach 0. The

solution of this differential equation is

$$Mkv^2 + R(p - p_0)^2 = Q, \tag{29}$$

which has to satisfy the initial condition of $p = p_1$, $v_1 = 0$, whence

$$R(p_1 - p_0)^2 = Q,$$

and with this value we obtain

$$\frac{(p - p_0)^2}{(p_1 - p_0)^2} + \frac{v^2}{(p_1 - p_0)^2 \frac{R}{kM}} = 1. \tag{30}$$

This is the equation of an ellipse identical with the Eq. 25 found by our previous mathematical analysis, q.e.d.

V. GENERAL SUMMARY OF THE GRAPHICAL METHOD.

On the basis of the foregoing examples it is possible to take a comprehensive bird's-eye view of the transient flow phenomena in hydraulic systems and their graphical analysis.

Two or more of the following elements constitute a hydraulic system: Pump, Pipe, Nozzle, Storer and Swinger; in which the Liquid undergoes changes of velocity and pressure, which are functions of time and location, $v = f_1(t, x)$ and $p = f_2(t, x)$. These phenomena can be represented in two sets of diagrams: (1) the v–p diagram and (2) the $v = f_1(t, x)$ and $p = f_2(t, x)$ functions, i.e., the stereograms of velocity and pressure. Each element has its characteristic representation in the v–p or t–x diagram, or both, and the first step in the graphical analysis of a given hydraulic system is to represent each element comprising the system in the v–p and t–x diagrams. Thus the pump is represented in the history diagram by its velocity-of-delivery curve; the nozzle in the v–p diagram by its efflux characteristic; the pipe in the v–p diagram by the direction-tangent $\tan \alpha$ and in the history diagram by the interval of single traverse L/a; the storer by its characteristic directrix $\tan \beta$ and the swinger by its characteristic directrix $\tan \gamma$, both in the v–p diagram. After these characteristics have been determined from the data of the problem, the procedure is to start from the initial given condition of the flow, and find, at the intersection of the characteristics of two adjoining elements, the flow condition existing after the elapse of the Δt

or L/a interval; then continue this procedure step by step and find each successive condition. It has to be borne in mind that if in the system the element B is located between, and connects, the elements A and C then the diagram will show a similar disposition of their respective characteristic lines, i.e., the characteristic of B will connect two points situated on the characteristic of A and C. From the v and p values thus obtained the stereograms of velocity and of pressure can be determined.

The possible combination of elements is infinite in number; but it is believed that the number of examples given is sufficient to serve as a guide to deal with other cases.

APPENDIX I. QUANTITIES AND SYMBOLS.

Into our considerations enter the following properties of the liquid, as expressed in either the English engineering system, i.e., in. lb. sec. (or ft. lb. sec.) or in the metric engineering system, i.e., cm. kg. sec. (or m. kg. sec.):

p = pressure (lb. in.$^{-2}$ or kg cm^{-2}),

v = velocity (in. sec^{-1} or ft. sec^{-1} or cm sec^{-1} or m sec^{-1}),

g = acceleration of gravity (386 in. sec^{-2} 32,17 ft. sec^{-2}, 980,66 cm sec^{-2}),

w = specific weight (lb. in.$^{-3}$ or kg cm^{-3}),

$\rho = \frac{w}{g}$ = density (lb. in.$^{-4}$ sec^2 or kg cm^{-4} sec^2),

$V = \frac{1}{\rho}$ = specific volume (in.^{4} lb.$^{-1}$ sec^{-2} or cm^4 kg^{-1} sec^{-2}),

γ = specific gravity = $\frac{\text{specific weight of liquid}}{\text{specific weight of water}}$ (dimensionless),

$k = V\frac{dp}{dV}$ = volume modulus of elasticity of liquid (lb. in.$^{-2}$ or kg cm^{-2}),

$a = \sqrt{kV} = \sqrt{k\frac{g}{w}} = V\sqrt{\frac{dp}{dV}}$ = acoustic velocity in liquid at rest in a rigid pipe (in. sec^{-1} or ft. sec^{-1} or m sec^{-1}),

$\frac{k}{a} = \sqrt{\frac{dp}{dV}}$ = proportionality factor denoting the ratio of pressure change to the corresponding velocity change in a pipe (lb. in.$^{-3}$ sec or kg cm^{-3} sec) which unites in itself all the properties of the liquid (V, w, k) which influence the surge phenomena.

The values pertaining to a given pressure are denoted by corresponding indices. Thus the values pertaining to zero pressure are: w_0, ρ_0, V_0, k_0, a_0 $(k/a)_0$.

These values, for a number of liquids and also solids and air, obtained or used by several investigators, are tabulated in Table I.

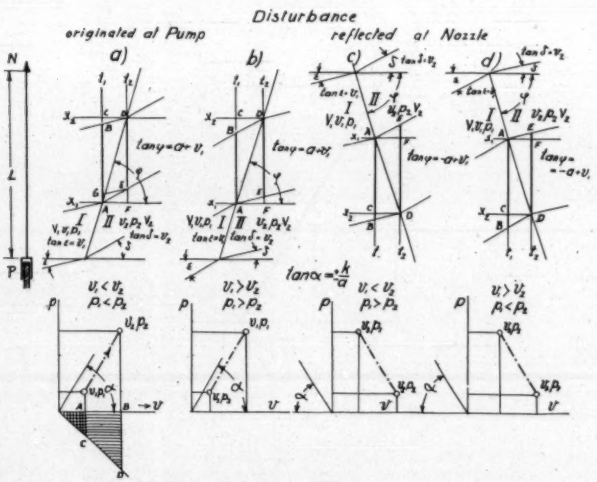
APPENDIX II. THE INTERRELATIONSHIP BETWEEN VELOCITY CHANGE AND PRESSURE CHANGE IN A LIQUID COLUMN.

In Fig. 35 is represented, in a time-distance chart, the history of a disturbance occurring in the liquid flow in a pipe L fed by pump P. The initial state of steady flow I (as characterized by the pressure p_1, velocity v_1 and specific volume V_1) is changed, by an instantaneous increase of pump-plunger velocity, into another state of steady flow II (characterized by p_2, v_2, V_2). The change can be visualized as taking place in a thin slice of the flowing column which may be called the "slice of demarcation." In front of this slice lies the portion of the column yet unaffected by the disturbance, i.e., having the initial state I; behind this slice lies the portion of the column already affected by the disturbance, i.e., characterized by the changed state II. The slice of demarcation is propagated along the pipe with the acoustic velocity in the moving column, i.e., with the velocity $a_1 + v_1$ and it attains at the instant t_1 the distance x_1 and at the instant t_2 the distance x_2. In the history diagram the position of this slice of demarcation is defined by a straight line forming a slope of $\tan \varphi = a_1 + v_1 = ds/dt$ with the time axis, which divides the t, x field into two zones I and II. In zone I the position of a liquid particle is defined by a straight line having the direction-tangent $\tan \epsilon = v_1$; in zone II the position of a liquid particle is defined by a straight line having

the direction tangent $\tan \delta = v_2$. It is our purpose to determine the interrelationship between the variables p_1, v_1, V_1, a_1, p_2, v_2, V_2.

Of these seven variables two are given by the initial state p_1, v_1 and the third is the changed velocity v_2. The remaining four cannot be chosen arbitrarily but are determined by a

FIG. 35.



Disturbance in a liquid column: (*a*) originated by increasing plunger velocity; (*b*) originated by decreasing plunger velocity; (*c*) originated by increased nozzle velocity; (*d*) originated by decreased nozzle velocity.

number of physical laws, namely:

(*a*) the equation of state of the liquid,
(*b*) the condition of continuity,
(*c*) the conservation of momentum,
(*d*) the conservation of energy.

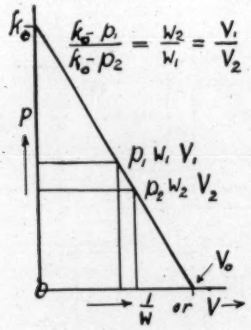
(*a*) *The Equation of State of the Liquid* establishes the interrelationship between the specific volume and the pressure of the liquid. In the pressure range in which we are inter-

ested this relationship is linear (Fig. 36) and can be expressed by the equation

$$p = \frac{k_0}{V_0}(V_0 - V_1), \tag{31}$$

in which k_0 is the volume modulus of elasticity at zero pressure, corresponding to V_0 specific volume. To any chosen V specific volume corresponds the pressure p and a volume

FIG. 36.



Equation of state of liquid.

modulus k which can be expressed

$$k = V\frac{dp}{dV} = \frac{V}{V_0}k_0. \tag{32}$$

For our problem the equation of state supplies two independent equations:

$$p_1 = \frac{k_0}{V_0}(V_0 - V_1) \quad \text{and} \quad p_2 = \frac{k_0}{V_0}(V_0 - V_2),$$

which can be combined into

$$p_2 - p_1 = \frac{k_0}{V_0}(V_1 - V_2). \tag{33}$$

(*b*) *The Principle of Continuity* can be stated as follows: The mass of a given portion of the liquid column is the same

before and after the change. If the initial length of the portion $L_1 = \overline{AB}$ occupies after the change the length $L_2 = \overline{DE}$ then it can be written:

$$\frac{L_2}{L_1} = \frac{V_2}{V_1} = \frac{\overline{AB}}{\overline{DE}} = \frac{\overline{AC} - \overline{CB}}{\overline{DF} - \overline{FE}} = \frac{(t_2 - t_1)[(a_1 + v_1) - v_1]}{(t_2 - t_1)[(a_1 + v_1) - v_2]},$$

whence

$$\frac{L_2}{L_1} = \frac{a_1 - (v_2 - v_1)}{a_1} = \frac{V_2}{V_1},$$

which can be written in the form

$$\frac{v_2 - v_1}{a_1} = \frac{V_1 - V_2}{V_1}. \tag{34}$$

Combining the Eqs. 33 and 34,

$$\frac{p_2 - p_1}{v_2 - v_1} = \frac{k_0 V_1}{V_0 a_1} \tag{35}$$

is obtained; taking Eq. 32 into consideration we obtain

$$\frac{p_2 - p_1}{v_2 - v_1} = \frac{k_1}{a_1} = \frac{k_0}{a_0} \tag{36}$$

as the fundamental equation on which the graphical method of analysis is based.

This equation contains the acoustic velocity a_1 the value of which is unknown yet, and which can be determined with the aid of the

(*c*) *Principle of Conservation of Momentum* which can be stated according to Newton's second law,

$$m\Delta v = P\Delta t,$$

which in our example can be expressed

$$\frac{Fa_1(t_2 - t_1)}{V_1}(v_2 - v_1) = F(p_2 - p_1)(t_2 - t_1),$$

whence

$$\frac{a_1}{V_1}(v_2 - v_1) = p_2 - p_1.$$

Combining this with Eq. 36 we obtain:

$$\frac{a_1}{V_1} = \frac{k_1}{a_1}, \qquad \text{and} \qquad a_1^2 = k_1 V_1 \tag{37}$$

as the velocity of propagation of disturbance in the liquid in its state I (p_1, V_1). The equations 31, 33, 34, 36, 37 give all the information sought in our problem. However, it has yet to be shown that these equations satisfy the

(*d*) *Principle of Conservation of Energy* which can be stated (neglecting the energy due to gravity, heat and friction) as follows:

In unit mass of liquid the energy input equals the sum of pressure-energy increase plus velocity-energy increase. In our problem (Fig. 35) the energy input during the change is: p_2 (vol. $\overline{EF}$); this accomplishes three amounts of work: (1) displaces the liquid column by the volume $\overline{CB}$ against pressure p_1; (2) compresses the liquid column from p_1 to p_2 pressure (i.e., with mean pressure $(\frac{1}{2}p_1 + p_2)$) in the volume $\overline{AG}$; (3) increases the velocity energy of the column: $\frac{1}{2}(v_2^2 - v_1^2) = \frac{1}{2}a/k(p_2 - p_1)(v_2 + v_1)$. For unit mass of liquid the above volumes can be expressed:

$$\text{vol. } \overline{EF} = \text{vol. } \overline{AB}\,\frac{v_2}{a} = \frac{V_1}{a}v_2 = \frac{a}{k}v_2,$$

$$\text{vol. } \overline{CB} = \text{vol. } \overline{AB}\,\frac{v_1}{a} = \frac{V_1}{a}v_1 = \frac{a}{k}v_1,$$

$$\text{vol. } \overline{AG} = V_1 - V_2 = (p_2 - p_1)\frac{a^2}{k^2} = \frac{a}{k}(v_2 - v_1).$$

With these values it can be written

$$p_2 v_2 \frac{a}{k} = p_1 v_1 \frac{a}{k} + \frac{1}{2}\frac{a}{k}(p_2 + p_1)(v_2 - v_1) + \frac{1}{2}\frac{a}{k}(p_2 - p_1)(v_2 + v_1), \tag{38}$$

whence

$$p_2 v_2 - p_1 v_1 = \tfrac{1}{2}[(p_2 + p_1)(v_2 - v_1) + (p_2 - p_1)(v_2 + v_1)], \tag{39}$$

which, after expanding, leads to an identity proving that the equations satisfy the principle of conservation of energy, q.e.d.

Our fundamental equation 36 was calculated for the case of forward wave of acceleration (i.e., the disturbance traveling away from the observer, and the disturbance consisting of an increase of velocity). The same result would have been attained for a forward wave of deceleration (Fig. 35*b*). In the case of a return wave (i.e., the disturbance traveling towards the observer as represented in Figs. 35*c*, *d*) the proportionality factor has a negative sign. Therefore, in a general form the fundamental equation can be written

$$\frac{\Delta p}{\Delta v} = \pm \frac{k_0}{a_0}, \tag{40}$$

the positive sign being valid for forward waves (away from the observer) and the negative sign for return waves (towards the observer). It is to be noted that the value of the proportionality factor is independent of the pressure. This becomes at once evident by remembering that the proportionality factor can be expressed as

$$\frac{k}{a} = \sqrt{\frac{dp}{dV}},$$

the right side of which is the square root of the slope of the $p = f(V)$ curve, which is, in the case of liquids, and in the range under consideration, a straight line, having, of course, a constant slope.

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R. RUEDENBERG: "Ueber die Fortpflanzungsgeschwindigkeit und Impulsstaerke von Verdichtungsstoessen." (Velocity of Propagation and Impulse-force of Compression Waves.) Artilleristische Monatshefte, Nr. 113 (1916), pp. 237–265 and 285–316.

Treats the velocity of propagation of compression waves in air with special reference to the phenomena in firing a gun.

I. SCHRODT: "Lineáris gázmozgások kisérleti vizsgálata uj mérési eljárással." (A New Method for the Experimental Investigation of Linear Gas Motions.) Doctor's thesis, University of Budapest, 1914.

After a thorough survey of the previous theoretical and experimental work in this field the author describes his own experiments, performed with a bolometer of extremely rapid response.

W. WAGENBLAST: "Wirkungen von Resonanzschwingungen in der Auspuffleitung von Vakuumpumpen." (Effects of Resonance in the Exhaust Pipe of Vacuum Pumps.) VDI, Forschungsheft 239, 1922.

G. EICHELBERG: "Zustandsaenderungen idealer Gase mit endlicher Geschwindigkeit." (Equations of State of Ideal Gases Assuming Finite Flow Velocity.) *Forschung*, 1934, Vol. 5, No. 3, pp. 127–129, 3 figs.

On the basis of the work of earlier investigators (especially of Hugoniot) the author analyses mathematically the propagation in a gas column of a disturbance initiated suddenly by a piston moving with constant velocity. Transition from static adiabate to dynamic adiabate; calculation of the work of compression with dynamic adiabate.

G. EICHELBERG: "Dynamische Vorgaenge in Luft und Brennstoffleitungen." (Dynamic Phenomena in Air Pipes and Fuel Injection Pipes.) *Zeitschrift der technischen Physik*, Vol. 13 (1932), p. 460.

A. KAUFMANN UND U. SCHMIDT: Schalldaempfer fuer Automobilmotoren. (Silencers for Automobile Engines.) M. Krayn Verlag, Berlin, 1932.

O. LUTZ: "Grundsaetzliche Betrachtungen ueber den Spuelvorgang an Zweitaktmaschinen." (Basic Considerations on the Scavenging Process in Two-cycle Engines.) *Forschung*, Vol. 5, 1934, S. 275.

O. KLUESENER: "Schwingungen in Saugleitungen von Verbrennungsmaschinen." (Oscillations in the Intake Pipe of Internal Combustion Engines.) Dieselmaschinen V, VDI, Berlin, 1932.

TH. SCHMIDT: "Schwingungen in Auspuffleitungen von Verbrennungsmotoren." (Oscillations in the Exhaust Pipe of Internal Combustion Engines.) *Forschung*, Vol. 5, 1934, S. 226.

E. SCHMIDT: "Schwingungen grosser Amplitude in Rohrleitungen." (Large-amplitude Oscillations in Pipelines.) *Z.d.V.D.I.*, Vol. 79 (1935), S. 671.

CLEMENS MAYER SCHUCHARD: "Schwingungen von Luftsaeulen mit grosser Amplitude." (Oscillation of Air Columns with Large Amplitude.) Dis-

sertation, Technische Hochschule Danzig. Forschungsheft 376 des V.D.I., 1936, pp. 12–22 with 39 figs.

These investigations have been made on an air column oscillating in a pipe line, excited by an opposed piston engine. Pressures were measured with an optico-mechanical indicator, velocities were measured with a hot-wire anemometer. At resonance of the exciting engine with the air column (which occurred at 7 per cent. greater frequency than the value calculated by theory) the waves have a step-shape front in which a sudden pressure jump of up to 0.38 at. occurs. The pressure ratio is 0.68 at max.; the time of the pressure jump is of the order of magnitude of a few thousandths of a sec. It is shown that this pressure jump is propagated along the whole pipeline with supersonic velocity.

V. Articles dealing with transient phenomena in mechanical springs.

W. HORT: Technische Schwingungslehre. (Previously cited.)

WILLY MARTI: "Ventilfeder schwingungen." (Vibrations of Valve Springs.) Doctor-Dissertation at the Technical University, Zurich. 21 p., 33 figs. Publ. G. Binkert A.-G. Winterthur, Schweiz, 1935.

An analytical and experimental investigation on spring surges; dynamic stresses; vibration of spring after a single lift-motion, as a function of speed; influence of the cam curve; criterion for resonance; influence of damping of initial spring tension, of back-lash in the roller.

ERRATA.

P. 465. $k = \sqrt{\frac{dp}{dV}}$; should read: $k = V\frac{dp}{dV}$.

P. 466. In Table I, end of first column: $\frac{a}{k}$ should read: $\frac{k}{a}$.

P. 468. Equation (8) should read: $\frac{x_2 - x_1}{t_2 - t_1} = \tan\varphi = a.$

P. 644. Line 13: Z_N should read: v_N.

P. 651. Caption for Figs. 25*d* and 25*e* should read: Storer of infinite volume, pipe and open nozzle.

Addition to Bibliography:

GEORGE CONSTANTINESCO: "Theory of Wave Transmission." Publ. by Walter Haddon, Proprietor of Patents Controlling Wave Transmission, 132 Salisbury Square, London E.C. 4. 1922. 209 pages, with 51 figs.

A complete theory of alternating fluid currents; effects of capacity, inertia, friction and leakage; waves in long pipes; theory of motors, generators, resonators, and transformers. These theories form the basis of the fluid-wave power transmission devices developed by Constantinesco and the W. H. Dorman & Co., Stafford, England.

THE DISCOVERY OF THE EXOTHERMIC ACTION OF ALUMINUM FOR THE PRODUCTION OF HIGH TEMPERATURES AT THE FRANKLIN INSTITUTE IN THE YEAR 1892.

BY

F. LYNWOOD GARRISON,

Member of the Institute.

One day about forty-five years ago three men stripped to the waist were firing a furnace in the basement of the old Franklin Institute building on Seventh Street, Philadelphia, endeavoring to raise the temperature of an old coke furnace from a bright red to white heat. They seemingly failed and withdrew the crucibles whose contents were not fused. The purpose of the experiment was to obtain metallic manganese free from carbon containing a minimum of iron and free as possible of other impurities.

For this objective the dioxide of manganese (pyrolusite MnO_2), or any other natural oxide, was first reduced to a monoxide (MnO) by heating in a stream of reducing gas, the oxide thus obtained being cooled down in this gas before exposure to the air, otherwise it would immediately absorb oxygen and be converted into the red protosesquioxide (Mn_3O_4), sometimes with sufficient energy to ignite spontaneously when subjected to the atmosphere before cooling. Despite the fact this monoxide had been mixed in crucibles with fluxes of lime and fluorspar and heated to a temperature as high as possible in this inefficient coke furnace, the reduction of the manganese monoxide to the metallic state was not effected. Moreover, it was found that the carbon from the graphite crucibles was absorbed or migrated into the charge, hence some other form of refractory container must be found along with a much higher temperature to effect the reduction and fusion.

As all three of these men were chemists to a greater or less degree they were not daunted. The elder was William H.

Wahl, native of Philadelphia, a graduate of Heidelberg University, Germany, and then Secretary of the Franklin Institute. The second man was the distinguished professor of chemistry in the Central High School of Philadelphia, William H. Greene. And the third a young mining engineer not long out of college, the present writer.

These difficulties seemed to us serious. The Franklin Institute had in those days had neither funds nor facilities for chemical or metallurigcal research; as a scientific organization it was extremely poor, its ordinary and essential activities being carried on by a small group of devoted and unselfish men who loved the Institute and the purposes for which it was founded.

The migration of carbon from the graphite crucibles into the charge was easily overcome by lining the pots with calcined magnesite ($MgCO_3$), a well known refractory. The second difficulty was more serious; how could we obtain the much higher temperatures with that old furnace necessary to fuse the charges in the crucibles and bring about the essential reaction? Every effort failed with our ordinary procedure; the proportions of the fluxes and character of the charges was changed a number of times without any notable improvement; the necessary heat could not be obtained in the furnace no matter how hard it was fired. Finally one of us, who had a flair for thermo-chemistry, suggested adding powdered or granulated aluminum (expensive in those days) to the charge. This was done and to our delight an enormously high temperature was easily obtained; the manganese oxide was reduced to metallic state wholly free from carbon and other objectionable impurities. It was thus evident we had hit upon something new in thermo-chemistry and metallurgy but at the time we wholly failed to realize its significance and future commercial or industrial importance. Our primary objective had been attained, which was the reduction of certain metallic oxides to a pure metallic condition, and in so doing we discovered the enormous heat-producing power it was possible to obtain by simply heating granulated aluminum with certain powdered or granulated metallic oxides.

The chemical reactions were relatively simple. It was estimated that fifty-five parts by weight of aluminum will

combine with about forty-eight parts by weight of oxygen to produce Al_2O_3 and in reacting with manganese oxide (MnO) will reduce two hundred and thirteen parts by weight of manganese oxide to metallic state. The following equation with the numerical values of the reacting substances indicates the transformation.

$$\begin{matrix}(55) & (213) & (103) & (165)\\ Al_2 + 3MnO = & Al_2O_3 + & 3Mn.\end{matrix}$$

In other words, roughly, one pound of aluminum will suffice to produce three pounds of metallic manganese from the oxide.

As is now well known this simple reaction is the basis of the so called "thermit process or thermit welding." The objective in this operation is not to reduce a metal from its oxides but to join by a restricted fusion two pieces of the same or different metals. For such a purpose it is necessary to use some cheap metallic oxide, the simplest and logical one being magnetic iron (magnetite, Fe_3O_4) in a finely divided condition. This reaction may be expressed as follows:

$$8Al + 3Fe_3O_4 = 9Fe + 4Al_2O_3.$$

Stated in weight, 217 parts of aluminum plus 732 parts of magnetite equal 540 parts iron and 409 parts slag or approximately three parts aluminum plus ten parts of magnetite will produce in the reaction seven parts of metallic iron. The aluminum of commercial thermit is in the state of fine division resembling granulated sugar and the iron of finely divided roll or other scale about the size of coarse sand. The temperature of the fusion is very difficult to determine, but is supposed to be in the neighborhood of 3000° Centigrade. The reaction is not necessarily explosive but the degree of heat required to ignite the charge is high, being about 1300° C. Barium peroxide is used as an ignition powder.

The affinity of aluminum at high temperatures for oxygen was not generally recognized and its practical utility recorded until these experiments at The Franklin Institute had been carried out by us.

On January 3, 1893, Greene and Wahl obtained their original patent No. 489,303 and the first public announcement of the discovery was made in a paper read before the Chemical

Section of the Franklin Institute on January 17, 1893, followed by a more exhaustive and elaborate paper read by myself at the Montreal meeting of the American Institute of Mining and Metallurgical Engineers, February 1893.[1]

On December 14, 1896, a United States patent No. 578,868 was granted to Hans Goldschmidt of Essen, Germany, for almost the same thing and in 1898 Goldschmidt appears to have used this method for welding together two pieces of iron or steel. In this patent Goldschmidt claims "I am able to produce refractory metals such as chromium, manganese, and the like in large quantities and on a commercial scale by mixing the metallic oxide with finely pulverized metallic aluminum and heating a small portion of the mixture."

In section 65 of the above Greene-Wahl patent (No. 489,303) it is stated and claimed as follows: "the herein described process which consists in reducing the ore to manganese monoxide, then in reducing said monoxide to the metallic state by heating it in contact with substantially the chemical equivalent quantity of a metal capable of removing its oxygen." It is obvious that the Greene-Wahl patent antedated that of Goldschmidt by nearly four years, namely January 3, 1893, and December 14, 1896.

From this conflict of assertive claims there arose extensive litigation. In the year 1913 the Goldschmidt Thermit Company brought suit in the United States Court for New Jersey against the American Vanadium for infrigement mainly on the ground that the Greene-Wahl discovery was simply a laboratory experiment never put to any practical use. This claim was rebutted by my own testimony as a witness in this suit to wit:

After Greene and Wahl had received their patent aforesaid they made arrangements with the Disston Saw Works at Tacony, Philadelphia, to use their steel melting furnaces for the production by their process of this carbonless metallic manganese in commercial quantities. During the year 1896 several hundred pounds of this metal were thus produced and sold. The Wilson Aluminum Company also made considerable quantities of this metal in the same way under a royalty

[1] *Transactions*, Vol. XXI, p. 887.

right or license sold them by Greene and Wahl. It would appear these commercial transactions and deliveries were made even before the above Goldschmidt patent was granted in December 14, 1896.

The Court in this litigation states "it is thus apparent that Goldschmidt did not discover nor does he assume to have done so, the aluminum reaction, but only a method by which the reaction could be initiated." [2] "Unquestionably, no one before Goldschmidt had discovered that the reaction could be started by internal heating." Thus in substance the Court held no infringement on the older Greene-Wahl patent took place because Goldschmidt heated or fired the charge from the inside of the container whereas Greene and Wahl produced the reaction from the outside. This hair-splitting decision affirmed something which in no way could be proved. What Greene and Wahl claimed was that heat initiated the reaction; no one can say in what part of the charge the reaction began.

Although at the time this valuable and outstanding discovery was made, Dr. William H. Wahl was the urbane and distinguished Secretary of the Franklin Institute, and its Committee on the Science and the Arts was functioning, no notice of this discovery appears to have been taken of his achievement. And Dr. Wahl as the leading official of the Institute may not have considered it proper to advance his interests in interfering with the work of this committee by seeking any personal recognition and award.

At any rate this was what happened. On June 21, 1904, the Science and the Arts Committee granted to Hans Goldschmidt the Elliott Cresson Gold Medal for the foregoing invention which he claimed to be his own with the following citation.

"It is the opinion of your sub-committee that the invention of Thermit and its application in welding and casting metals, constitutes a great step in advance in the production and utilization of high temperatures. While it is recognized that Dr. Goldschmidt was not the first one, either to observe or to apply the heat

[2] Cases Re Litigation on Goldschmidt Patent No. 578, 868. Goldschmidt Thermit Co. *v.* American Vanadium Co., 291 Fed. 81, 1916. District Court, D. New Jersey. Also Goldschmidt Thermit Co. *v.* Primos Chemical Co., 292 Fed. 362, 1923. (CCA, Third Circuit.)

liberated in the reduction of metallic oxides with aluminum, he must be credited with having developed the manufacture of Thermit, with the practical application of the enormous heat stored in this product, and with extraordinary perseverence and resourcefulness in bringing these inventions to commercial success and thereby creating a new industry."

This report was published in full in the JOURNAL OF THE FRANKLIN INSTITUTE September 1903 under the title "Goldschmidt's System of Alumino-Thermics." [3] In this document no mention or reference is made of the fact the Secretary of the Institute eleven years before had developed the same discovery and as I have shown made practical and a limited commercial use of it.

While nothing can now be done to change this award and assertion of discovery, I feel in justice to the memory of our past devoted and distinguished Secretary, who was also an old and highly esteemed friend of mine, and to whom I owe much for helpful and unselfish advice and direction in my younger years, this brief and simple statement is due if for no other reason that I am now the only person living who was associated with Greene and Wahl in the carrying out of the initial experiments. The simple truth of the subject should become a matter of record in the publications of The Franklin Institute. My connection with the invention ceased shortly after the production of the metal was begun at the Disston Works as I was later employed professionally in the West and in China. At the time the above mentioned Science and the Arts Committee report appeared I was in South America; consequently I was not personally familiar with the discussions relating to the subject which then occurred, nor was I then a member of the Science and the Arts Committee. Otherwise I would have undoubtedly protested the committee's action.

[3] Page 187.

THE PRACTICE OF THEORY.

Accomplishing the Impossible.

BY

W. N. JENNINGS,

Member of the Institute.

After the boy, Jamie Watt, had made a pop-gun of his mother's tea-kettle by corking its spout and weighting its lid, he sat down on the kitchen fender to do a little thinking.

"Why not put that toy to work?" But the fussy kitchen clock ticked a great many times before Watt watched his first "Condensing Engine" pump water out of a coal mine; for theory and practice are always miles apart.

Returning one night with my father, after my first wonderful day in New York, our train stopped at a place called "Menlo Park."

"What are those twinkling lights on the embankment, Dad?" I asked.

"A crack-pot called Edison is trying to bottle sunlight," he said, and went blinking back to his Wool Market Report, under a smoky, smelly oil-lamp.

Standing before the great Corliss Steam Engine at the Centennial Exposition, an open-mouthed, pop-eyed crowd entirely overlooked, and almost upset the exhibit of a tall, dreamy-eyed, fleecy-faced individual, one Alexander Bell, who vainly sought to interest capital in a toy he called a "Telephone"; but it took the keen eye and acute ear of a Brazilian Emperor to sense the greatest invention of modern times, and to turn the tide Bell's way; starting the world to listening in; making the Bell Telephone the talk of the town and the Wonder of the World.

When a crazy cockney first walked a London street, during a heavy rainy downpour under a peripatetic tent which

he called an 'umbrella,' it soon became the target for rotten eggs and decayed vegetables, and it was a long time before another brave soul risked an avalanche of ridicule.

When a fool called Murdock had lighted up his factory in Soho with gas obtained from coal, and proposed to pipe the streets of London to carry this deadly, dangerous explosive to private houses, he was literally laughed out of town. Tallow dips and oil lamps were good enough for conservative old John Bull.

Many years afterward I saw a "Protest Parade" wending its way down Broad Street in the City of Brotherly Love, to denounce the erection of a Gas Works; and another wholesale exhibition of conservatism took place in the same way to protest against the installation of the electric trolley and the stringing of highly charged copper conductors over the public streets; when any school boy could tell you that copper wire corrodes and electric current kills. Away with these crack-brains who would menace pedestrians.

There was many a shaking head and frowning face at the proposed erection of water works with underground pipes to convey drinking water to our homes, the precious fluid that some people had the audacity to use for bathing purposes, and there was much talk of frozen pipes, flooded cellars and floating corpses. "Why change the sane and safe hand-pump?"

When John Fitch announced that he would on a certain day propel a boat by steam-power from Philadelphia to Trenton, *upstream*, there came from the banks of the Delaware a mighty gale of laughter; for that, surely, was the height of absurdity. Any fool could tell you that steam could not overcome gravity. But it did; and those who came to jeer were the loudest to cheer.

And poor Professor Langley, dubbed by many "Darius Green Number Two," with his theory of human flight upon which he had worked many years before he built his steam

driven "Aerodrome," and watched it upon its first flight splash and sink in the Potomac; but, alas, not living to see that selfsame airplane make several successful flights when furnished with a modern gasoline motor.

Taking a leaf from Langley's book, the two shy, modest, Wright Brothers sought the seclusion of lonely Kitty Hawk to make a practical test of their theory of human flight, and to evade the smarting ridicule of the Press. How did they fit Practice to Theory?

The answer comes to us now day and night without ceasing, in the steady drone of the Wright motor anywhere up in the sky.

The practice of theory is no light task; for the Conservatist is smug and soulless, and ridicule is a brake on the wheel of progress; but before the mind's eye of the Pioneer burns a steady light that leads him on to final accomplishment; for

> As they watch the valiant son
> Start out to do what can't be done,
> The gods are wise; they understand
> He does not need a helping hand.
> The Pioneer will find each day
> Rocks, ruts and ridges in the way
> To give him strength to dare and do
> And make at last his Dream come true.

Mercury in Small Boilers.—(*Power Plant Engineering*, Vol. XLI, No. 4.) Important modifications in design are incorporated in the application of the mercury vapor cycle in the two small installations in the shops of the General Electric Co. at Pittsfield and Lynn. In each case the installation consists of a mercury boiler, mercury turbine, a condenser-boiler and a steam turbine. The mercury turbines are rated at 1000 kw. and the condenser boiler supplies 12,500 lb. per hr. of 185 lb. ga. steam, which will be sufficient for the generation of another 900 kw. of electric energy. The boiler at Pittsfield is of the natural circulation type with tubes similar to liquid mercury cooling walls elsewhere. The unit at Lynn is of the forced circulation type with all the heating tubes filled with liquid mercury and all the vapor formed in a separate chamber remote from the combustion space. Vapor is generated by discharging from the heating tubes through a nozzle which drops the pressure and releases the stored heat of the liquid, a portion of which flashes into vapor, the pressure in the heating tubes being approximately 200 lb. per sq. in. greater than in the flash chamber. This arrangement was evolved to eliminate the transition zone in the combustion space from liquid to vapor, in which difficulty in "wetting" the metal surfaces had been encountered. Difficulties of leakage, equalization, air infiltration and solubility have been overcome by progress in welding. The plants at Schenectady and Kearny require 7½ lb. of mercury per kilowatt of capacity. The new designs require about 6 lb.

R. H. O.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

THE VARIATION WITH ALTITUDE OF THE PRODUCTION OF BURSTS OF COSMIC-RAY IONIZATION.*

BY

C. G. MONTGOMERY and D. D. MONTGOMERY.

The frequency distribution of large cosmic-ray showers has been found [1] to be represented satisfactorily by a relation of the form $R = A/N^s$, where N is the number of rays in the shower, RdN the rate of occurrence of showers having sizes between N and $N + dN$, and A and s are parameters. Distribution curves, taken from several observers, for showers from lead are shown, in Fig. 1, to be well represented by this relation when the rates of occurrence of the smaller showers, which values are uncertain because of the statistical fluctuations in the ionization, are disregarded. The sizes of the bursts of ionization have been reduced to numbers of rays by somewhat arbitrary assumptions, since sufficient information for the proper reduction was not, in all cases, available. The factors used do not influence the values of s, but cause proportional errors in A. Table I gives values of s and the sources of the data plotted. The value of R for 100-ray showers is of the order of 10^{-5} per hour per cc. of lead at sea level for thicknesses of the order of one centimeter.

The assumption of a distribution curve of this form has interesting consequences when applied to measurements of burst production at different elevations. Figure 2 shows measurements, previously reported,[2] for bursts from lead and magnesium at sea level and at an elevation of 4300 meters. It appears from this that the value of s, although characteristic of the material, is independent of elevation. Although the ratio of the frequencies of occurrence of bursts of a given

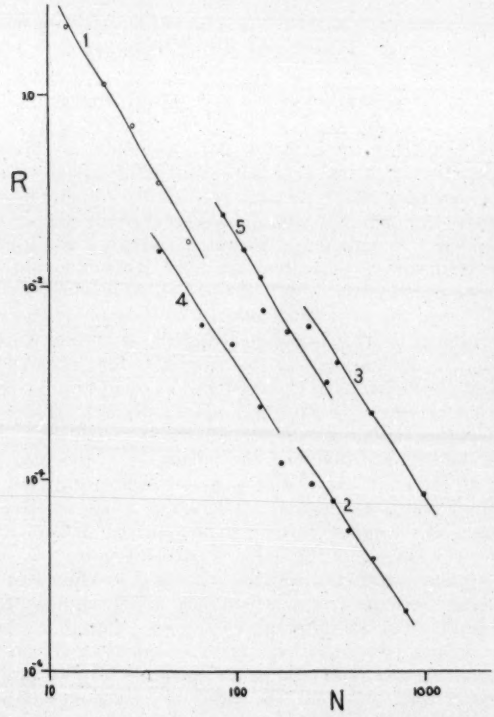
* Reprinted from the *Physical Review*, **48**, 969 (1935).

[1] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **48**, 786 (1935).

[2] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **47**, 429 (1935).

size at different altitudes is very different for the two substances, the ratio of the sizes of bursts which occur at a given rate at the two elevations is very nearly the same.

FIG. 1.

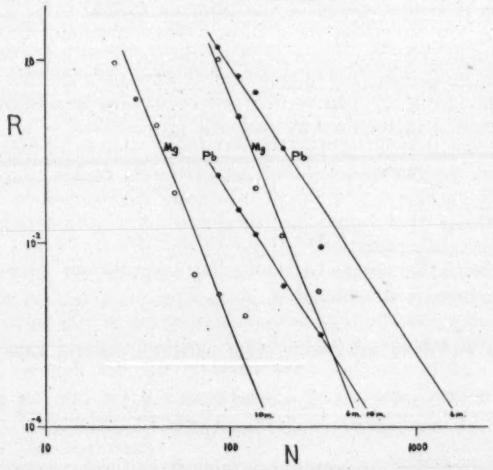


This is also true for the observations at the intermediate elevations where measurements were made. This suggests that the process which produces a shower of a given size at sea level would occur at the same rate at a high elevation,

TABLE I.

Curve	Observer	Reference	s	Remarks
1	J. C. Street and R. T. Young	*Phys. Rev.*, **47**, 572 (1935)	3.4	Computed to the basis of 60 ions/cm./ray
2	E. G. Steinke and H. Schindler	*Zeits. f. Physik*, **75**, 115 (1932)	3.1	Assumed 4.8×10^3 ions per ray
3	R. Bennett, G. Brown, and H. A. Rahmel	*Phys. Rev.*, **47**, 435 (1935)	3.1	Mt. Evans data, assumed 2×10^5 ions per ray
4	W. Messerschmidt	G. Hoffmann, Papers and Discussions, Int. Conf. on Physics, London, 1934, I, p. 226	3.1	Assumed 9×10^4 ions/ray
5	C. G. Montgomery and D. D. Montgomery	*Phys. Rev.*, **47**, 429 (1935)	3.3	2×10^5 ions/ray
		mean	3.2	

FIG. 2.



but would there produce a shower of a larger size, and that this increase is independent of the shower producing material.

If we make this assumption, it can be stated mathe-

matically that the quantity

$$\left[\frac{A(h_1, Z)}{A(h_2, Z)}\right]^{1/s(Z)}$$

is independent of Z, where h_1 and h_2 are two elevations, and Z the atomic number.

This is equivalent to the differential relation

$$\frac{\partial}{\partial Z}\left(\frac{1}{s}\frac{1}{A}\frac{\partial A}{\partial h}\right) = 0,$$

whose solution is

$$A = A_0(Z)[F(h)]^{s(Z)}.$$

This immediately suggests the expression postulated by Professor W. F. G. Swann:[3]

$$A = A_0 E^{\alpha},$$

where E is the energy of the primary cosmic rays, and A_0 and α are functions of Z only. Since Swann's theory is consistent with the observed variation with altitude for the bursts from lead and magnesium, it appears that the shape of the frequency distribution curve is determined by the exponent α in such a way that s is proportional to α. It is to be noted that the fact that the observed variations with altitude of the frequency of occurrence of bursts from lead and magnesium are different is entirely inconsistent with the hypothesis that bursts are produced by a soft component of the cosmic radiation.

The authors wish to thank Professor Swann for helpful discussions of this matter.

CAN PROTONS REPRESENT THE PRIMARY COSMIC RAYS AT SEA LEVEL? *

BY

W. F. G. SWANN.

Analyses of the cosmic-ray intensity-altitude curves have appeared to suggest the conclusion that the primary cosmic

[3] W. F. G. Swann, *Phys. Rev.*, **48**, 641 (1935).

* Reprinted from the *Physical Review*, **49**, 478 (1936).

radiation in the vicinity of the earth is composed exclusively of protons.[1] The purpose of this letter is to point out certain difficulties inherent in this view.

A charged particle is characterized by the fact that its ionization increases enormously towards the end of its range, so that, in the case of protons and alpha-particles, large and measurable spurts of ionization should be produced in relatively short distances by those rays which are ending their journeys.

Let r be the distance from the end of the range to the point where the ionization per centimeter of path is σ. Then all rays producing more ions per centimeter than σ will be absorbed within the distance r; and, on a view which considers the rays as the observed entities disappearing according to an exponential law of absorption, the fraction disappearing within the distance r is $(1 - e^{-\mu r})$ where μ is the observed absorption coefficient. This is the fraction of the rays which would produce at the point considered more than σ ions per centimeter of path at atmospheric pressure, and so, more than $Lp\sigma$ ions in a distance L at a pressure p. If we assign 54,000 ions as the lower limit of a spurt which is to be considered in the measurements, the corresponding value of σ is $\sigma = 54{,}000/Lp$. In a vertical cylinder of length L and cross-sectional area a, the number of spurts greater than 54,000 ions should consequently be, with sufficient approximation, S, where

$$S = (Na^2/L^2)(1 - e^{-\mu r}). \qquad (1)$$

N is here the number of rays per square centimeter per second per unit solid angle at the vertical and is equal to 0.013. The value of r is that corresponding to the above value of σ and must be obtained by extrapolation of the experimental data through the aid of Bethe's formula for energy loss.[2] Thus we find for a case where $L = 15.2$ cm. and $p = 10$

[1] A. H. Compton and H. Bethe, *Nature*, 134, 734 (1934); also A. H. Compton, *Rev. Sci. Inst.*, 7, 71 (1936).

[2] H. Bethe, *Zeits. f. Physik*, 76, 293 (1932); see also P. M. S. Blackett, *Proc. Roy. Soc.*, A135, 132 (1932). Extrapolation of the experimental results by aid of the theory is enhanced in validity by the fact that experiments have checked the theory for electrons, for the range of velocity contemplated in the calculations for protons. Ionization per centimeter of path has been obtained from energy loss on the assumption that 30 volts corresponds to one ion.

atmospheres, the value $r = 2700$ cm. Compton quotes $\mu = 0.08$ per meter of water for proton cosmic rays, so that, with proper adjustments of units, (1) gives, for a cylinder with $L = 15.2$ cm. and $a = 45.6$ cm.^{2}, a value $S = 1.2$ spurts per hour greater than 54,000 ions.

At my suggestion, an experiment of the above type, later to be described in detail, has been performed by C. G. and D. D. Montgomery, W. E. Ramsey, and myself. The measured value of S was found to be less than 0.11 spurt per hour. It will suffice to say that alpha-particles were eliminated by observing only coincident spurts in the upper and lower halves of the vessel, and "showers" were detected and eliminated by Geiger-counter devices.

In view of the above considerations it would seem that if protons are to be admitted at all they must function in some such manner as that implied in the writer's theory,[3] through the production of secondary rays which then become the entities actually observed by our counters.

THE COLLECTION OF ISOTOPES.*

BY

L. H. RUMBAUGH.

Since the discovery of isotopes of non-radioactive elements, many attempts have been made to obtain pure specimens of isotopes in quantities sufficient for study of their individual properties. The separation of the isotopes of hydrogen by repeated electrolysis of water has led to important discoveries in physics and chemistry. The isotopes of no other elements differ sufficiently for the successful application of methods suitable to hydrogen, so it becomes necessary to use some form of mass spectrometer to isolate their pure isotopes. Two years ago 10^{-6} grams of lithium isotopes were separated at California Institute of Technology by a mass spectrometer of special design, and shortly afterward, at Cambridge,

[3] W. F. G. Swann, *Phys. Rev.*, **48**, 641 (1935).

* A supplementary progress report concerning one of the investigations resulting from a grant made by the American Philosophical Society to W. F. G. Swann for furtherance of work in nuclear physics by himself and his collaborators. Miscellanea, Vol. 1, No. 2, pp. 50–51, December, 1935.

England, samples of 10^{-8} grams of lithium were obtained by analogous methods, an amount sufficiently large for the identification of part of the nuclear processes which occur in the transmutation of lithium by proton and deuteron bombardment. Otherwise, previous attempts to obtain pure isotopic specimens in usable amounts have been unsuccessful.

To meet this problem, a magnetic lens type of mass spectrometer has been developed at the Bartol Research Foundation. In this instrument the positive ions emitted from a large area (20 to 30 cm.^{2}) pass through a uniform magnetic field whose boundaries are so shaped that the ions are sorted as to mass and focussed into slits beyond the field.

In the case of lithium, the centers of these slits are separated 3.6 cm. and lie on the "focal line" which is inclined 52° to the axis of the convergent ion beam. The mass number resolution for lithium, as measured with a one mm. slit, is shown in the appended diagram, Fig. 1. The total (or wide slit) current from Li^7 was 0.1 mA., corresponding to a deposition rate of about 2.5×10^{-5} grams of Li per hour.

Specimens of the two lithium isotopes totaling 1.1 milligrams were collected simultaneously in sixty hours. Li^6 constitutes 7 per cent. of the total. The fraction of Li^6 decreased from 7.65 per cent. to 6.1 per cent. during the collection. Figure 2 is a photograph of the two isotopic specimens deposited on copper discs as spots three-eighths of an inch in diameter.

These specimens are to be used in studying the nuclear reactions of Li^6 and Li^7 when bombarded with protons, deuterons, and neutrons.

Preliminary tests have indicated that potassium can be deposited at a rate of 0.1 to 0.2 milligrams per hour with the main isotopes, K^{39} and K^{41} resolved. The newly discovered isotope K^{40} was not resolved, but should be increased many fold in concentration so that the origin of the natural radioactivity of potassium can be established.

The significant feature of this work is that over one thousand times the quantity of lithium isotopes previously reported by other workers has been separated. It is demonstrated that usable amounts of other elements may be separated into their isotopic constituents.

Highway Safety Study.—A comprehensive program of research into the causes of highway accidents is now under way according to a report to Congress by the Secretary of Agriculture. The Bureau of Public Roads is cooperating with nationally recognized agencies in the field of highway safety. Particular attention is being given to a study of the lack of uniformity in State motor-vehicle laws, which is regarded as an important contributing cause of highway accidents. There is also underway a study of the characteristics and habits of drivers and identification of dangerous drivers. All available information relating to drivers is being collected for study. A digest of the results of previous research is expected to throw light upon means of detecting those personal traits that predispose individual drivers to accidents and that point to means of controlling drivers with such traits. The Bureau reports that the accident expectancy of the average driver is one accident in about 25 years. Therefore, drivers who have accidents more frequently should be detected and watched. One step in this direction will be the collection and study of accident records of 25,000 drivers over the past 6 years. This study will reveal what percentage of drivers menace the safety of themselves and others. It will also show whether data now collected furnish an adequate basis for predicting the driver's future performance. Physical and psychological tests of drivers also are to be made to measure skills assumed to be essential to safe driving. By measuring the skill and driving ability of numerous drivers, and comparing the results with their accident records, it may be possible to develop methods that will positively identify safe and unsafe drivers. Such methods could be used by authorities in issuing, suspending and revoking driver permits.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

RAPID ELECTRODEPOSITION OF IRON FROM FERROUS CHLORIDE BATHS.

Many of the plates used at the Bureau of Engraving and Printing for printing currency and securities are made by electrodeposition of nickel and iron, and are finally coated with a thin, very hard layer of chromium. In studying the methods used in making these plates, Charles Kasper of the Electrochemistry Section of the National Bureau of Standards has found that by careful control of the temperature and acidity of the iron chloride bath, it is possible to deposit the iron (which makes up most of the printing plate) at the rate of about twelve thousandths of an inch per hour. This is about five times the usual rate. The favorable conditions are more critical, and hence the rapid process is chiefly useful for special occasions, for example, when new designs of plates are first made. A more detailed account of this discovery will be found in the May number of the *Journal of Research* (RP991).

MEASURING THE THICKNESS OF NICKEL COATINGS.

In general, the protective value of nickel coatings on either steel or brass, including those covered with the usual thin chromium layer, depends largely upon the thickness of the nickel. This has usually been specified in terms of the average thickness, but now a certain minimum thickness is often required.

Rapid methods of measuring the thickness at any point are therefore desirable. Most of the methods now used destroy the coating or the article. In RP994, which will be published in the May number of the *Journal of Research*, A. Brenner describes a non-destructive method for measuring the thickness of nickel coatings on metals such as brass and zinc.

*Communicated by the Director.

A small spring balance is used to measure the force of attraction between the nickel coating and a small permanent magnet. The thickness of the nickel is indicated by the reading of the dial, which is standardized against a similar nickel coating of known thickness. Before testing nickel coatings of unknown source, they should be annealed for a short time at 400° C. (750° F.).

It is believed that this method will prove useful for factory control of the plating on such articles as brass hardware and plumbing fixtures.

A CONTRIBUTION TO THE CHEMISTRY OF RHENIUM.

Rhenium, the discovery of which was announced in 1925, is the last member of the family of the elements which has been isolated and is available in sufficient amount to permit general investigations of its properties. Many of its chemical reactions are still matters of considerable uncertainty, in spite of the numerous articles which have appeared in the past few years.

G. E. F. Lundell and H. B. Knowles of the Bureau's Chemistry Division recently studied the behavior of rhenium when dilute solutions of potassium perrhenate are acidified with sulphuric acid, cooled and passed through a column of amalgamated zinc. This indicates that rhenium forms a compound in which it has a valency of minus one, and that the rhenium in this compound is oxidized to a valency of plus one if the diluted sulphuric acid solution is protected from oxygen and warmed to approximately 50° C.

In the course of the investigation, which will be reported in full in the May number of the Journal of Research (RP999), it was also found (1) that rhenium can be electrodeposited from diluted (5 + 95) sulphuric acid solution, (2) that deposits are slightly contaminated, and (3) that the deposited metal can be oxidized directly to perrhenic acid by exposure to moist air, oxygen, or by making the deposit the anode in a water solution.

CHEMISTRY OF WOOL.

In a talk at the Boston meeting of the New England Section, American Association of Textile Chemists and

Colorists on April 2, Milton Harris, research associate of the Association at the Bureau discussed the chemistry of wool and similar substances from the standpoint of practical wool processing and the part these materials play in everyday life.

Wool belongs to a class of proteins known as the keratins. These materials are characterized by a high sulfur content, practically all of which is present in the form of the amino acid cystine, and by their great resistance to bacterial and enzyme attack. Because of their great stability they are considered as protective tissues, and it is interesting to note that nature has provided the human and animal bodies with an abundance of keratin in the form of hair, finger nails, epidermis, etc. The sulfur containing amino acid, cystine, has been found to have an important role in the studies relating to arthritis, diabetes, and cancer research. As a result, a great amount of research has been done on this compound and it has been shown, for example, that alteration of the state of the sulfur in insulin destroys the physiological activity of this material for diabetic treatment.

The results of a research program on the chemistry of wool, now in progress at the Bureau for the American Association of Textile Chemists and Colorists has indicated a similarly important role for sulfur in wool research. Protein chains in the wool molecule appear to be linked together by sulfur in the form of disulfide groups which account for a considerable portion of the stability of the wool molecule. However, it has been shown that any reagent which will alter the state of these disulfide groups, will alter or destroy the physical structure of the fiber as a whole. In general, these groups are extremely susceptible to attack by oxidizing and reducing agents, light, and alkalies. It is possible under suitable conditions to oxidize wool so that from all outward appearances, it is practically unchanged and yet the incipient damage in the wool may be so great as to render the wool nearly worthless. The methods which were worked out for the study of oxidized wool may be utilized in the control of practical bleaching, chlorination, and bromination processes.

From the standpoint of such practical processes as dyeing and carbonizing, the researches on the acid and basic properties of wool have been most fruitful. The acidic groups

account for the absorption of alkalies and basic dyes by wool whereas the basic groups react with acids and acid dyes. The acid dyeing process has been shown to be governed by simple chemical laws. Treatment of the fiber with nitrous acid, hydrogen peroxide, chlorine, and bromine decreases the basicity and correspondingly decreases the affinity of wool for acid dyes. The basic groups may react with sulfuric acid in two ways; namely, to form an acid salt in which the acid is readily removed by alkalies or replaceable by acid dyes, or to form a stable sulfuric acid which decreases the affinity of wool for acid dyes. It is the formation of the latter compound which causes the resist often obtained in the carbonizing process.

EFFECT OF SIZING, WEAVING AND ABRASION ON THE PHYSICAL PROPERTIES OF COTTON YARN.

An investigation is being conducted by the Bureau in cooperation with the Alabama Polytechnic Institute, on the effect of weaving and abrasion on the physical properties possessed by cotton yarn before and after it is sized with white potato starch. Breaking strength, elongation at rupture, elongation under a load of 35 grams, and permanent set after this load was removed, were measured on unsized yarns and on yarns sized with varying amounts of white potato starch. The sized yarns had higher strength, lower elongation at rupture and at a load of 35 grams, and a lower permanent set after removal of the load than the unsized yarn.

The effect of weaving on these properties and on the increase in length was determined for both sized and unsized yarn. A machine was constructed for simulating the abrading and pulling action of the loom, and data were obtained on the physical properties of sized and unsized yarns which had been exposed for varying periods to the action of this machine. Weaving or abrading in this machine caused a slight decrease in strength, and had little effect on elongation or permanent set on both sized and unsized yarn. Either operation caused a small increase in length of unsized but not of sized yarn.

The results of this work are reported in RP933 by Walter T. Schreiber, M. N. V. Geib, and O. C. Moore, which will be published in the May number of the *Journal of Research*.

Methods are suggested for establishing control tests in the mill to determine whether the yarn has been properly sized.

GLASS CONTENT OF PORTLAND CEMENT CLINKER.

At the clinkering temperatures attained by present day methods of portland cement manufacture, a considerable part of the charge is present as a liquid phase. When the clinker is cooled rapidly, from the clinker temperature, part of the liquid phase will be present as an "undercooled liquid" or glass. RP997 by William Lerch and Lorrin T. Brownmiller, which will be published in the May number of the *Journal of Research*, describes a method of approximating the glass content of portland cement clinker. The method is dependent on the heat changes involved in passing from a non-crystalline state (glass) to a crystalline state.

AMERICAN STANDARD SPECIFICATION FOR DRY CELLS AND BATTERIES.

The publication of a revision of the American Standard for dry cells in Circular C414 of the National Bureau of Standards calls for a brief history of the project.

A committee of the American Electrochemical Society recommended standard methods for testing dry cells in 1912. Although much has been accomplished in developing specifications for dry cells since that time, the influence of these early recommendations on some of the tests now in use is still discernible.

The preparation of nationally recognized specifications to include sizes of cells, arrangement of the cells in batteries, tests and required performance, began in 1917 with the drafting of specifications which were later approved by representatives of manufacturers, the War Industries Board and several Governmental departments. These specifications were published in the Bureau of Standards' Circular, No. 79, on Dry Cells. A revision was made in 1921 and this was later approved as standard specification of the Government.

In 1924 the need for a more permanent and representative committee to deal with recurring revisions of the specifications

became apparent, with the result that the American Engineering Standards Committee (now the American Standards Association) authorized the formation of a sectional committee on dry cells under the sponsorship of the National Bureau of Standards. This committee of 22 members, including representatives of manufacturers, the largest commercial consumers, the Government and several independent associations, has been active since its organization in 1926 in preparing three revisions of the specifications which became American Standards in 1928, 1930 and 1937.

Close cooperation has been maintained between this committee and another committee charged with responsibility for preparing Federal Specifications on the same subject. Federal Specifications issued in 1931 and 1935 have been concordant with the American Standard specifications although differing in form.

Periodic revisions of the American Standard Specification for dry cells become necessary as a result of changes in the art. New types and uses for batteries require new tests. Notable improvements in the capacity and performance of dry cells within recent years justify increased requirements. The new specification of 1937 reflects the advances made in the better grades of cells. In general, the capacity of the better dry cells and batteries has been increased three to four fold since the specifications of 1917 were prepared. The result has been considerable gain to the public at large.

Copies of the new Circular are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, MAY 19, 1937.

The stated monthly meeting of the Institute was called to order at 3:30 o'clock in the afternoon, by the President of the Institute, Mr. Phillip C. Staples. The President stated that the minutes of the April meeting had been printed in full in the May issue of the JOURNAL of the Institute, and that if there were no objections, the minutes would stand approved as printed.

He then announced that the next business was the presentation of the medals which had been recommended by the Committee on Science and the Arts, and the award of certificates of honorary membership. The order of the awards proceeded as follows:

Presentation of Longstreth Medals to	Sponsor
EMILE MONNIN CHAMOT, Ph.D., Professor of Chemistry, Cornell University, Ithaca, New York, and RICHARD T. ERBAN, Consulting Gas Engineer, New York City, New York.	Dr. J. S. Hepburn. Dr. C. D. Galloway.
JOHN S. HAUG, Consulting Gas Engineer, United Engineers and Constructors, Inc., Philadelphia, Pennsylvania.	Mr. W. H. Fulweiler.
HAROLD SINCLAIR, Director, Hydraulic Coupling and Engineering Company, Ltd., Middlesex, England.	Mr. F. H. Rogers.
HERBERT L. WHITTEMORE, Chief, Engineering Mechanics Section, Bureau of Standards, Washington, D. C.	Mr. W. P. Valentine.
Presentation of Henderson Medal to	
RUPEN EKSERGIAN, Ph.D., E. G. Budd Manufacturing Company, Philadelphia, Pennsylvania.	Mr. H. H. Quimby.
Presentation of Levy Medal to	
INGE LYSE, Professor of Engineering Materials, Lehigh University, Bethlehem, Pennsylvania	Capt. H. B. Ely.

	Sponsor
Presentation of Potts Medal to JOHN CLYDE HOSTETTER, Sc.D., Vice-President, Hartford-Empire Company, Hartford, Connecticut.	Mr. J. D. Lee, Jr.
Presentation of Cresson Medals to CARL DAVID ANDERSON, Ph.D., California Institute of Technology, Pasadena, California.	Dr. T. D. Cope.
WILLIAM BOWIE, Sc.D., LL.D., United States Coast and Geodetic Survey (retired), Washington, D. C.	Dr. C. B. Bazzoni.
JACQUES EDWIN BRANDENBERGER, Neuilly-sur-Seine, France.	Mr. Lionel F. Levy.
WILLIAM FRANCIS GIAUQUE, Ph.D., University of California, Berkeley, California.	Mr. R. H. Oppermann.
ERNEST ORLANDO LAWRENCE, Ph.D., Director, Radiation Laboratory, University of California, Berkeley, California.	Mr. E. L. Forstall.

Presentation of the Franklin Medal and Certificate of Honorary Membership to

ROBERT ANDREWS MILLIKAN, Ph.D., D.Sc., LL.D.,
Director, Norman Bridge Laboratory of Physics,
California Institute of Technology,
Pasadena, California.

Presentation of the Franklin Medal and Certificate of Honorary Membership to

PETER DEBYE, Ph.D.,
Director, Kaiser Wilhelm Institut fur Physik,
Berlin, Germany.

Papers

"Exploring the Stratosphere for New Electrical Effects"

by

Dr. Robert A. Millikan.

"Structure in Electrolytic Solutions"

by

Dr. Peter Debye.

Adjourned.

HENRY BUTLER ALLEN,
Secretary.

(An extended account of the proceedings of Medal Day will be published in an early issue of the JOURNAL.)

LIBRARY NOTES.

The library is open for consultation as follows: Mondays, Tuesdays, Fridays and Saturdays 9 A.M. until 5 P.M., Wednesdays and Thursdays, 2 until 10 o'clock P.M. 810 readers made use of its facilities during the twenty-six days of April.

RECENT ADDITIONS.

Agriculture and Forestry.

GUSTAFSON, A. F. Conservation of the Soil. 1937.

Aviation.

Aircraft Year Book for 1937.

Biography.

BELL, ERIC TEMPLE. Men of Mathematics. 1937.

Royal Society of London. Obituary Notices of Fellows. Nos. 1–5. 1932–1936.

THOMSON, SIR J. J. Recollections and Reflections. 1936.

Chemistry and Chemical Technology.

BELL, L. M. T. The Making and Moulding of Plastics. 1936.

DONDER, TH. DE AND PIERRE VAN RYSSELBERGHE. Thermodynamic Theory of Affinity. A Book of Principles. 1936.

EINECKE, ERICH. Das Gallium. Eine kritische Würdigung der Erkenntnisse mit experimentellen Beiträgen. 1937.

HALLA, FRANZ, AND HERMANN MARK. Leitfaden für die Röntgenographische Untersuchung von Kristallen. 1937.

Handbook of Butane-Propane Gases. Supplement to the Second Edition. 1937.

HOHN, HANS. Chemische Analysen mit dem Polarographen. 1937. Anleitungen für die chemische Laboratoriumspraxis. Band 3.

JELLINEK, KARL. Lehrbuch der physikalischen Chemie. Fünfter Band. Erste und zweite Auflage. 1937.

MITCHELL, C. AINSWORTH. Inks: Their Composition and Manufacture Including Methods of Examination and a Full List of British Patents. Being the Fourth Edition of Mitchell and Hepworth's "Inks," Thoroughly Revised and Reset. 1937.

SIDGWICK, N. V. The Organic Chemistry of Nitrogen. New Edition Revised and Rewritten by T. W. J. Taylor and Wilson Baker. 1937.

Verein Deutscher Ingenieure. Kunst-und Pressstoffe. 1. 1937.

Civil Engineering.

COLLINS, H. JOHN, AND C. A. HART. Principles of Road Engineering. 1936. The Roadmakers' Library Volume 6.

GRINTER, LINTON E. Theory of Modern Steel Structures. Volume 1: Statically Determinate Structures; Volume 2: Statically Indeterminate Structures and Space Frames. 1936–1937.

Economics.

HEWITT, ABRAM S. Selected Writings of Abram S. Hewitt. Edited by Allan Nevins with an Introduction by Nicholas Murray Butler. 1937.

VERMILYE, WILLIAM M. Economic Trends in Manufacturing and Sales. 1937.

Electricity and Electrical Engineering.

EVERITT, WILLIAM LITTELL. Communication Engineering. Second Edition. 1937.

GHIRARDI, ALFRED A. Radio Field Service Data. Second Revised Edition. 1936.

HIRST, A. W. Electricity and Magnetism. 1937.

LYON, WALDO V. Applications of the Method of Symmetrical Components. First Edition. 1937. Electrical Engineering texts.

Engineering.

SCHMALTZ, GUSTAV. Technische Oberflächenkunde Feingestalt und Eigenschaften von Grenzflächen technischer Körper insbesondere der Maschinenteile. 1936.

Hygiene and Physiology.

EDDY, WALTER H., AND GILBERT DALLDORF. The Avitaminoses. The Chemical, Clinical and Pathological Aspects of the Vitamin Deficiency Diseases. 1937.

Manufactures.

GLAFEY, HUGO. Textil-Lexikon. Handwörterbuch der gesamten Textilkunde. 1937.

ROUTSON, H. W. The Lockeyist. 1937.

Mathematics.

ALLISTON, NORMAN. Mathematical Snack Bar. A Collection of Notes and Results. 1936.

BELL, ERIC TEMPLE. The Handmaiden of the Sciences. 1937.

Mechanical Engineering.

American Society of Refrigerating Engineers. The Refrigerating Data Book. The Third Edition 1937–38.

ROSBLOOM, JULIUS. Diesel Handbook. Fourth Edition. 1937.

Metallurgy.

EVANS, ULICK R. Metallic Corrosion, Passivity and Protection. 1937.

Mining Engineering.

DAVY, HUMPHRY. Über die Sicherheitslampe zur Verhütung von Explosionen in Gruben, gasbeleuchteten Häusern, Spritlagern oder Schiffsräumen u. dgl. Mit einigen Untersuchungen über die Flamme. Aus dem Englischen übersetzt und herausgegeben von Klaus Clusius. Ostwalds Klassiker der exakten Wissenschaften No. 242. 1937.

Naval Architecture and Navigation.

CHAPELLE, HOWARD I. Yacht Designing and Planning for Yachtsmen, Students and Amateurs. 1936.

CUGLE, CHARLES H. Cugle's Examination Guide for Lifeboat Men and Seamen. 1937.

RIESENBERG, FELIX. Standard Seamanship for the Merchant Service. Second Edition. 1936.

Photography.

Museum of Modern Art, New York. Photography 1839–1937. With an Introduction by Beaumont Newhall. 1937.

U. S. Army. Surgeon-General's Office. The Use of the Röntgen Ray by the Medical Department of the United States Army in the War with Spain (1898). Prepared by W. C. Borden. 1900.

Physics.

BOMKE, HANS. Vakuumspektroskopie. 1937.

BRETSCHER, E., Editor. Kernphysik. Vorträge gehalten am Physikalischen Institut der Eidgenössischen Technischen Hochschule, Zürich im Sommer 1936. 1936.

DRUCKER, C., ed. Ostwald-Luther Hand-und Hilfsbuch zur Ausführung physiko-chemischer Messungen. Fünfte, neubearbeitete Auflage. 1931.

JAMESON, ALEX. H. An Introduction to Fluid Mechanics. 1937.

KUNERTH, WILLIAM. A Text-Book of Illumination. Second Edition. 1936.

STEVENS, BLAMEY. The Identity Theory. Second Edition, Revised and Amplified. 1936.

Railroad Engineering.

RAYMOND, WILLIAM G. Elements of Railroad Engineering. Revised by Henry E. Riggs and Walter C. Sadler. Fifth Edition. Rewritten and Enlarged. 1937.

Sanitary Engineering.

EHLERS, VICTOR M., AND ERNEST W. STEEL. Municipal and Rural Sanitation. Second Edition. 1937.

Scientific Essays.

TRELEASE, SAM F., AND EMMA SAREPTA YULE. Preparation of Scientific and Technical Papers. Third Edition. 1936.

BOOK REVIEWS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 587, Blower Cooling of Finned Cylinders, by Oscar W. Schey and Herman H. Ellerbrock, Jr. 12 pages, diagrams, 23 × 29 cms. Washington, Government Printing Office, 1937. Price ten cents.

Several electrically heated finned steel cylinders enclosed in jackets were cooled by air from a blower. The effect of the air conditions and fin dimensions on the average surface heat-transfer coefficient q and the power required to force the air around the cylinders were determined. Tests were conducted at air velocities between the fins from 10 to 130 miles per hour and at specific weights of the air varying from 0.046 to 0.074 pound per cubic foot. The fin dimensions of the cylinders covered a range of fin pitches from 0.057 to 0.25 inch, average fin thicknesses from 0.035 to 0.04 inch, and fin widths from 0.67 to 1.22 inches.

The value of q, based on the difference between the cylinder temperature and the inlet-air temperature, varied as the 0.667 power of the weight velocity of the cooling air for cylinders having spaces from 0.077 to 0.21 inch between fins. Below 0.077-inch space the exponent of the curves increased for each successive

decrease in space. The value of q was independent of fin width for the range of widths tested and decreased as the space between the fins decreased.

The power required for cooling, neglecting the kinetic energy lost from the exit of the jacket, varied as the 2.69 power of the weight velocity for a given specific weight and inversely as the square of the specific weight for a given weight velocity of the cooling air. For a given weight velocity of the cooling air or a given power and for a fin width of 1.22 inches, the fin space giving the maximum heat transfer was approximately 0.045 inch.

Report No. 588, Fuel Spray and Flame Formation in a Compression-Ignition Engine Employing Air Flow, by A. M. Rothrock and C. D. Waldron. 15 pages, plates, 23 × 29 cms. Washington, Government Printing Office, 1937. Price ten cents.

The effects of air flow on fuel spray and flame formation in a high-speed compression-ignition engine have been investigated by means of the N.A.C.A. combustion apparatus. The process was studied by examining high-speed motion pictures taken at the rate of 2,200 frames a second. The combustion chamber was of the flat-disk type used in previous experiments with this apparatus. The air flow was produced by a rectangular displacer mounted on top of the engine piston. Three fuel-injection nozzles were tested: a 0.020-inch single-orifice nozzle, a 6-orifice nozzle, and a slit nozzle. The air velocity within the combustion chamber was estimated to reach a value of 425 feet a second.

The results show that in no case was the form of the fuel spray completely destroyed by the air jet although in some cases the direction of the spray was changed and the spray envelope was carried away by the moving air. When the fuel distribution within the combustion chamber was particularly poor, the volume in the chamber reached by the flame was considerably increased by the air flow. When the distribution was reasonably good, there was little change in the distribution of the flame. It was found that the air movement set up during the induction of air through ports in the cylinder liner, under a pressure difference of 26 inches of Hg, could be controlled so as materially to aid the air flow set up during the last portion of the compression stroke.

PUBLICATIONS RECEIVED.

Pascal, The Life of Genius, by Morris Bishop. 398 pages, portrait, 16 × 24 cms. Baltimore, The Williams and Wilkins Company, 1936. Price $3.50.

The World of Atoms, Twelve Non-Mathematical Lectures, by Arthur Haas. Second edition, enlarged and revised, translated by George B. Welch. 183 pages, illustrations, 16 × 24 cms. New York, D. Van Nostrand Company, Inc., 1937. Price $3.00.

Atomic Spectra, and the Vector Model, by A. C. Candler. Volume I, Series Spectra; Volume II, Complex Spectra. Two volumes, 14 × 22 cms. Cambridge, the University Press, 1937. Price $8.50.

Organic Chemistry Laboratory Guide, by E. Wertheim. 524 pages, illustrations, 21 × 28 cms. Philadelphia, P. Blakiston's Son & Company, Inc., 1937. Price $2.00.

Atomic Spectra and Atomic Structure, by Gerhard Herzberg. Translated with the co-operation of the author by J. W. T. Spinks. 257 pages, illustrations, 15 × 23 cms. New York, Prentice-Hall, Inc., 1937. Price $4.25.

Univers Isomorphes et Constantes Physiques, par L. Counson. 40 pages, 21 × 27 cms. Liege Editions E.D.K., 1937.

The Mathematical Theory of a New Relativity, Chapter XIII, The Law of Gravitation (With three important predictions) by the Honorable Dr. Sir Shah Sulaiman. 20 pages, 18 × 25 cms. reprinted from the National Academy of Sciences, India, 1936.

The Mathematical Theory of a New Relativity, Chapter XIV, The Rotational Mechanics, by the Honorable Dr. Sir Shah Sulaiman. 20 pages, illustrations, 18 × 25 cms. Reprinted from the Proceedings of the National Academy of Sciences, India, 1936.

National Advisory Committee for Aeronautics. Technical Notes. No. 598, Wind Tunnel tests of a Clark Y wing with "Maxwell" leading-edge slots by William E. Gauvain. 6 pages, diagrams. No. 600, Discharge characteristics of a double injection-valve single-pump injection system by Dana W. Lee and E. T. Marsh. 10 pages, diagrams. Two pamphlets, 20 × 26 cms. Washington, Committee, 1937.

National Bureau of Standards, Miscellaneous publication M 154. Summary report of the National Bureau of Standards Research on the preservation of records by A. E. Kimberly and B. W. Scribner, 28 pages, illustrations, plate, 15 × 23 cms. Washington, Government Printing Office, 1937. Price 10¢.

CURRENT TOPICS.

Paint for Seawater Concrete.—(*Engineering News Record*, Vol. 118, No. 12.) This form of protection has been found desirable on some of the waterfront structures erected and maintained on San Francisco Bay by the Board of State Harbor Commissioners. The impervious protective coating is the result of many years testing. It is a compound of roofing asphalt with a melting point of not less than 150 deg. F. and 10 per cent. of raw China wood oil. The compound is applied hot (about 250 to 300 deg. F.). It may be applied with a spray gun. The coating does not harden and become brittle, but even after years of service retains a sufficient elasticity to prevent cracking or peeling off. It is suggested that for warmer climates a somewhat different percentage of the two ingredients might be desirable. Prior to application it is desirable to treat the surface with a priming coat to pick up loose particles and fill the pores. A very satisfactory primer can be made from the compound by thinning it with a cut-back of some sort. The compound was developed by Mr. A. A. M. Russell, testing engineer of the Board.

R. H. O.

Electric Boiler Heats City Building.—(*Electrical World*, Vol. 107, No. 13.) Seattle City Light Building installation demonstrates how electricity can be employed economically for the heating of water, such as in the conversion of building heating systems where hot water circulation is already installed. It embodies mechanical and electrical features which are new in heating unit design. The boiler consists of 90 tubes, each 10 ft. long. Its capacity is 900 kw. Each of the 90 tubes is a two tube assembly consisting of a 3 in. "fire" tube contained in a 4 in. water tube. The tubes are mounted at an angle to the horizontal and water circulates upward and forward between the 3 and 4 in. tubes. Each heating unit is a 10 ft. nichrome, U-shaped ribbon which is run into the 3 in. tube, closed end first. The 90 units are divided electrically into six sections. The fifteen units of each section are star connected, ungrounded. Control is provided by magnetic contactors, operated by air thermostats on the supply header.

R. H. O.

INDEX TO VOLUME 223.

January to June, 1937.

Akeley, Edward S.: Tensors associated with a pair of quadratic differential forms, 199

Aluminum, the discovery of the exothermic action of (Garrison), 779

Ballantine, Stuart: On a formula of Rayleigh for velocity potential, 508

Beams, J. W.; L. B. Snoddy; H. Trotter, Jr.; & W. T. Ham, Jr.: Impulse circuits for obtaining a time separation between the appearance of potential at different points in a system, 55

Book Reviews:

American Institute of Mining and Metallurgical Engineers, Transactions, Vol. 120, Iron and Steel Division, 127

Bell, E. T.: The handmaiden of the sciences, 670

Bragg, W. L.: Electricity, 405

Bretscher, E.: Kernphysik, 668

Bush, G. L.: Senior science socialized for the high school, 405

Champion, F. C. & N. Davy: Properties of matter, 543

Crenshaw, B. H. & C. D. Killebrew: Analytic geometry and calculus, 543

Cugle, C. H.: Cugle's examination guide for lifeboat men and seamen, 671

Donder, Th. de & P. Van Ryssel-berghe: Thermodynamic theory of affinity, 671

Dorr, J. V. N.: Cyanidation and concentration of gold and silver ores, 258

Eddington, A.: Relativity theory of protons and electrons, 403

Espe W. & M. Knoll: Werkstoff-Kunde der hochvakuumtechnik, 256

Eyring, C. F.: A survey course in physics, 126

Feather, N.: An introduction to nuclear physics, 404

Fischer, J.: Einführung in die klassische elektrodynamik, 666

Foster, P. F.: The mechanical testing of metals and alloys, 407

Fröhlich, H.: Elektronentheorie der metalle, 545

Ghirardi, A. A.: Radio field service data, 672

Hirst, A. W.: Electricity and magnetism, 669

Jastrow, J.: The story of human error, 544

Jordan, P.: Anschauliche quantentheorie, 542

Keenan, J. H. & F. G. Keyes: Thermodynamic properties of steam, 257

Kent, R. T.: Power, 126

MacDougall, F. H.: Physical chemistry, 403

Meldrum, W. B. & F. T. Gucker: Introduction to theoretical chemistry, 261

Millikan, R. A.; D. Roller & E. C. Watson: Mechanics, molecular physics, heat and sound, 406

National Advisory Committee for Aeronautics, Report: No. 562, 261; No. 567, 402; No. 568, 262; No. 570, 545; No. 571, 263; No. 572, 402; No. 573, 400; No. 574, 401; No. 575, 673; No. 577, 546; No. 578, 401; No. 579, 673; No. 580, 402; No. 581, 674; No. 582, 674; No. 583, 546; No. 584, 674; No. 587, 807; No. 588, 808

Nevins, A.: Selected writings of Abram S. Hewitt, 668

Page, N. C.: Lessons and problems in electricity, 257

Pender, H., W. A. Del Mar & K. McIlwain: Electric power, 126

Pender, H., & K. McIlwain: Electric communication and electronics, 126

Rasetti, F.: Elements of nuclear physics, 541
Robinson, D. M.: Dielectric phenomena in high voltage cables, 667
Stevens, B.: The identity theory, 670
Trelease, S. F. & E. S. Yule: Preparation of scientific and technical papers, 672
Wilson, A. H.: The theory of metals, 667
Briggs, Lyman J.: Some problems of the National Bureau of Standards, 1

Carlson, Albert S.: Economic geography—Its importance to America, 269
Clocks showing mean and sidereal time simultaneously (Hope-Jones), 95
Competitive system and industrial growth (Pew), 683
Cosmic radiation in matter. Absorption of (Nye), 173
Cosmic ray meter. High altitude, test of radio-equipped (Keen), 355
Cosmic-ray measurements in the stratosphere. Radio-transmission of coincidence counter (Johnson), 339
Cosmic rays. A terrestrial origin for (Holmes), 495
Current topics: 22, 112, 129, 146, 265, 316, 338, 374, 378, 386, 409, 442, 494, 510, 512, 526, 536, 564, 608, 634, 677, 698, 788, 796, 810

Daylight. Ultraviolet energy in (Luckiesh, Taylor & Kerr), 699
De Juhasz, Kalman J.: Graphical analysis of transient phenomena in linear flow, 463, 643, 751

Economic geography—Its importance to America (Carlson), 269
Economic trends in manufacturing and sales (Vermilye), 23
Einstein, Albert and N. Rosen: On gravitational waves, 43
Electrical network, linear, with lumped parameters. The design of a mechanical analogy for the general (Pawley), 179

Fernberger, Samuel W.: Mendel and his place in the development of genetics, 147
Fluid flow. Graphical analysis of transient phenomena in (De Juhasz), 463, 643, 751
Franklin, Benjamin. Dissertations relating to geologic phenomena (Garrison), 635
Franklin Institute.
Bartol Research Foundation:
Communication, no. 94: Radio-transmission of coincidence counter cosmic-ray measurements in the stratosphere (Johnson), 339
Financial statements, 118
Notes, 379, 513, 789
Biochemical Research Foundation, Financial statements, 121
Progress (McDonald), 317
Board of Managers: Resolution passed on the occasion of the death of Dr. Elihu Thomson, 538
Financial statements, 114
Library notes: 124, 254, 398, 539, 664, 805
Monthly meeting: December 16, 1936, 113; January 20, 1937, 251; February 18, 1937, 397; March 17, 1937, 537; April 21, 1937, 663; May 19, 1937, 803
Science and the Arts Committee. Abstract of Proceedings: December 9, 1936, 114; January 13, 1937, 253; February 10, 1937, 398; March 10, 1937, 538; April 14, 663
Franklin Institute. Story of the (Wright), 417, 565, 731

Garrison, F. Lynwood: Benjamin Franklin's dissertations relating to geologic phenomena, 635
Garrison, F. Lynwood: The discovery of the exothermic action of aluminum for the production of high

temperatures at The Franklin Institute in the year 1892, 779
Gravitational Waves (Einstein & Rosen), 43
Greene & Wahl: Discovery of the exothermic action of aluminum (Garrison), 779

Ham, W. T., Jr.; L. B. Snoddy; H. Trotter, Jr.; & J. W. Beams: Impulse circuits for obtaining a time separation between the appearance of potential at different points in a system, 55
Hellweg, J. F.: Time determination and time broadcast, 549
Henry, D. E. & H. C. Rentschler: Photo-electric emission, 135
Hepburn, Joseph Samuel & Paul Reveri Miraglia: A contribution to the chemistry of turkey eggs, 375
High altitude test of radio-equipped cosmic ray meter (Keen), 355
Holmes, M. C.: A terrestrial origin for cosmic rays, 495
Hope-Jones, F.: Clocks showing mean and sidereal time simultaneously, 95
Howland, W. E. & J. D. Richetta: Derivation of coefficients of orifices, 83

Ideology. Traditional (Merrill), 511
Impulse circuits for obtaining a time separation between the appearance of potential at different points in a system (Snoddy, Trotter, Ham & Beams), 55
Industrial growth and the competitive system (Pew), 683

Jennings, Wm. N.: The practice of theory, 785
Jodidi, S. L.: A new maturity test of peas, 593
Johnson, Thomas H.: Radio-transmission of coincidence counter cosmic-ray measurements in the stratosphere, 339

Keen, C. D.: High altitude test of radio-equipped cosmic ray meter, 355
Kerr, G. P.; Matthew Luckiesh & A. H. Taylor: Ultraviolet energy in daylight—A two year record, 699
Kneas, Frank N.: Bearing values of soils, 443

Linear flow. Transient phenomena in (De Juhasz) 463, 643, 751
Luckiesh, Matthew; A. H. Taylor & G. D. Kerr: Ultraviolet energy in daylight—A two year record, 699
Luckiesh, Matthew & Frank K. Moss: The visibility of various type faces, 77

McDonald Ellice: Progress of the Biochemical Research Foundation of The Franklin Institute, 317
McKay, A. T. & N. W. McLachlan: On a formula of Rayleigh for velocity potential, 501
McLachlan, N. W. & A. T. McKay: On a formula of Rayleigh for velocity potential, 501
Manufacturing and sales. Economic trends in (Vermilye), 23
Materials. Particulate, law of size distribution and description of (Roller), 609
Mendel and his place in the development of genetics (Fernberger), 147
Merrill, A. A.: Traditional ideology, 511
Miraglia, Paul Reveri & Joseph Samuel Hepburn: A contribution to the chemistry of turkey eggs, 375
Moss, Frank K. & Matthew Luckiesh: The visibility of various type faces, 77

National Bureau of Standards: Notes, 101, 243, 387, 527, 655, 797
National Bureau of Standards. Some problems of (Briggs), 1
Nye, Arthur Wickes: Absorption of cosmic radiation in matter, 173

Orifices, coefficients of, derivation of (Howland & Richetta), 83

Pawley, Myron: The design of a mechanical analogy for the general linear electrical network with lumped parameters, 179
Peas. A new maturity test of (Jodidi), 593
Pew, J. Howard: Industrial growth and the competitive system, 683
Photoelastic analysis of T-tail stresses (Ryan), 715
Photo-electric emission (Rentschler & Henry), 135
Potential at different points in a system. Impulse circuits for obtaining a time separation between the appearance of (Snoddy, Trotter, Ham & Beams), 55
Publications received: 127, 263, 407, 547, 675, 808

Rayleigh formula for velocity potential (McLachlan & McKay), 501
Rayleigh formula for velocity potential (Ballantine), 508
Rentschler, H. C. & D. E. Henry: Photo-electric emission, 135
Richetta, J. D. & W. E. Howland: Derivation of coefficients of orifices, 83
Roller, Paul S.: Law of size distribution and statistical description of particulate materials, 609
Rosen, N. and Albert Einstein: On gravitational waves, 43
Ryan, James J.: Photoelastic analysis of T-tail stresses, 715

Shenstone effect. An investigation of the (Weber), 215
Snoddy, L. B.; H. Trotter, Jr.; W. T. Ham, Jr.; & J. W. Beams: Impulse circuits for obtaining a time separation between the appearance of potential at different points in a system, 55
Soils. Bearing values of (Kneas), 443

Taylor, A. H.; Matthew Luckiesh & G. P. Kerr: Ultraviolet energy in daylight—A two year record, 699
Tensors associated with a pair of quadratic differential forms (Akeley), 199
Theory. The practice of (Jennings), 785
Time broadcast and time determination (Hellweg), 549
Time determination and time broadcast (Hellweg), 549
Time, mean and sidereal, clocks showing simultaneously (Hope-Jones), 95
Traditional ideology (Merrill), 511
Transient phenomena in linear flow. Graphical analysis of (De Juhasz), 463, 643, 751
Trotter, H., Jr.; L. B. Snoddy; W. T. Ham, Jr.; & J. W. Beams: Impulse circuits for obtaining a time separation between the appearance of potential at different points in a system, 55
Turkey eggs. A contribution to the chemistry of (Hepburn & Miraglia), 375
Type faces. The visibility of various (Luckiesh & Moss), 77

Ultraviolet energy in daylight (Luckiesh, Taylor & Kerr), 699

Velocity potential. On a formula of Rayleigh for (McLachlan & McKay), 501
Vermilye, William M.: Economic trends in manufacturing and sales, 23
Visibility of various type faces (Luckiesh & Moss), 77

Wahl, Wm. H.: The discovery of the exothermic action of aluminum (Garrison), 779
Weber, Alfred H.: An investigation of the Shenstone effect, 215
Wright, Sydney L.: The story of The Franklin Institute, 417, 565, 731